Patent
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	
John Hulls et al.	Group Art Unit: 3635
Application No.: 10/074,684	Examiner: Basil S. Katcheves
Filed: February 11, 2002	Confirmation No.: 9166
For: FORCE-RESISTING DEVICES AND METHODS FOR STRUCTURES	

DECLARATION BY INVENTORS UNDER 37 C.F.R. § 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

We, John Hulls and Rory R. Davis, hereby state as follows:

1. I, Rory R. Davis, am a citizen of the United States and I, John Hulls, am a citizen of the United Kingdom.

2. We are the inventors of the invention disclosed and claimed in the United States Patent Application No. 10/074,684, filed under 35 U.S.C. ∋ 111 on February 11, 2002, entitled "FORCE-RESISTING DEVICES AND METHODS FOR STRUCTURES."

3. We are making this declaration for the purpose of traversing the rejections contained in the USPTO office communication dated November 12, 2004 based on United States Patent No. 6,761,001 B2.

4. Attached is a copy of our Declaration (13 pages) including supporting material (Appendices A to G). The Declaration presents facts and supporting materials comparing the subject matter of the present application, including the present claims, with the disclosure in United States Patent No. 6,761,001 B2.

5. We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: ________________ ____________________
John Hulls

Date: 04-08-2005 Rory R. Davis
Rory R. Davis

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Date: 7 APRIL 05 ______________________
John Hulls

Date: ______________________ ______________________
Rory R. Davis

DECLARATION OF THE INVENTORS UNDER 37 C.F.R. § 1.132

I. Introduction

This declaration discusses and analyzes the "lateral motion device" (hereafter the "Mueller device")[1] disclosed in U.S. Patent No. 6,761,001 B2 issued to Mueller (hereafter the Mueller '001 patent) in comparison with the Applicant's claims in U.S. Patent Application No. 10/074,684.

Detailed analysis and evidence is presented in this Declaration concerning the Mueller Device, Applicant's Active Element with its claimed force versus deflection properties, stiffness, forces and loads, and mechanical and structural differences. In each instance, differences between the Mueller Device and the present claims and/or the allegations in the Official Action have been noted. Also, the criticality of the force versus deflection property with respect to the claimed Active Element has been discussed.

As discussed herein, the Mueller device has a force versus deflection property that is elastic and does not have a plastic region or response as claimed in the present application. In fact, the Mueller '001 patent teaches one of ordinary skill to avoid plastic deformation (See sections III. A-B and Appendix A).

II. Summary

Applicant's claimed Active Element differs substantially from the Mueller device both functionally and structurally.

<u>No Plasticity In The Mueller Device</u>

In the Mueller device, forces are collected along the horizontal axis and transmitted to a multiple-spring and rigid structure system that only operates in the elastic range because springs merely absorb energy when loaded and then give it back when unloaded. The Mueller device has force versus deflection properties that become continuously stiffer as it deflects. This is known to one skilled in the art as a "hardening" system. Such a system is detrimental to energy dissipation. (See sections III. A-B for detailed discussion.)

In contrast, the claimed Active Element directly receives shear forces on both the horizontal and vertical axis, receives and transmits loads from multiple or distributed locations, and energy is absorbed and dissipated (i.e., dissipated as is commonly known by one skilled in the art, see Appendix A regarding Mueller's misapplication of this term). The Active Element has defined force versus deflection properties that initially is elastic up to a selected level of force; then the Active Element will begin to deform plastically, and the slope of the force/deflection curve will decrease in a controlled, gradual (or selected)

[1] Several devices are disclosed in USP 6,761,001 B2, but the specific Mueller Device discussed and analyzed in this declaration is one associated with the rejection in the Official Action dated November 12, 2004. Similar analysis can be conducted on the other devices disclosed in the Mueller patent.

manner as deflection increases. This is known to one skilled in the art as a "softening" system, resulting in the unexpected improvement of high energy dissipation. (See sections III. A-B for detailed discussion.)

> Elasticity can be defined as "a property of a material by virtue of which deformation caused by stress disappears upon removal of the stress".

> Plasticity can be defined as "non recoverable deformation beyond the point of yielding". Note: non-recoverable means deformation is "permanent", i.e. not elastic. Plasticity is controllable in a cyclic manner by the Active Element. It is the novel design of the Active Element that allows repetitive plastic distortion, such as may result from earthquake and other forces applied to a building.

> Rigidity can be defined as "a rigid body is one that does not deform during its motion."

As is seen by the evidence provided herein, the Mueller device simply transfers loads from an upper portion of a wall to a foundation via an added spring and rigid structure system, and does not provide plasticity. The Mueller device with its springs and rigid (vs. plastic) structures[2], e.g. (Fig 14: 100); (Fig 10: 970); (Fig. 8: assembly, spring/sheet unit, V shape rigid structure), cannot be considered to be an Active Element.

Whereas, the claimed Active Element transmits forces, and both absorbs (via elasticity) and strongly dissipates (via plasticity) energy across the many discontinuous structural elements of a building (See, e.g., present application's abstract). The Active Element device, by definition of Applicant's specification, provides specially designed cyclic elastoplastic properties, with the claimed plasticity resulting in high energy dissipation.

Criticality of Claimed Properties

The present application and this declaration show criticality in the claimed properties, for example, illustrating the unexpected improvement in properties of building structures under shear forces, e.g., enabling structures incorporating the Active Element to match or compliment the general characteristics of a standard code shear wall while greatly increasing energy dissipation. It is shown that the Active Element device is designed to resist forces and reduce stresses and replace stiffness, dissipation, and strength to a structure that incorporates openings, etc… such that the structure behaves substantially as if such discontinuous structural elements have not been formed therein. (See sections III-IV; Appendices C and G for detailed discussion).

[2] Plasticity (a form of deformation) is nearly the opposite of rigidity (does not deform during motion).

Mechanical and Structural Differences

The Mueller device is a composite assembly, comprising springs and rigid structures, and is a single point "collective load system". The composite Mueller device is limited to attachment to the upper portion of a wall at one end and the foundation at a second end.

Utilizing a different engineering method and structure, the claimed Active Element is a non-planar sheet metal [3] "distributive load system", that operates within an elastic range and additionally incorporates the mechanism of plasticity. The Active Element when installed in a structure, generally extends along the edges or boundary between two discontinuous structural elements or about an opening such that all the components of the shear forces are fed into the Active Element along the entire discontinuity between structural elements or a portion thereof, or about an opening or portion thereof. The Active Element does not employ the use of mechanical springs, nor does it necessarily require direct foundation attachment. (See section V for detailed discussion.)

Conclusions

The Mueller Device does not have a force versus deflection property including an elastic region and a plastic region wherein, in the plastic region, deflection increases more per unit load than in the elastic region as load increases (claims 22 and 43), nor does the Mueller Device have a force versus deflection property that is elastic in a first range of forces and that is plastic in a second range of forces, the second range of forces greater than the first range of forces, and wherein in the second range of forces, deflection increases more per unit load than in the first range of forces (claims 170 and 171).

In the Mueller '001 patent, it is unobvious to one of ordinary skill in the art to utilize the mechanism of plasticity, resulting in strong hysteresis and energy dissipation, as a critical means to mitigate earthquake damage in buildings, because there is a very complex technical tradeoff between allowing deflection (which can be destructive itself) and providing energy dissipation using that deflection (which in turn can reduce total deflection compared to a conventional shear wall). In fact, the Mueller '001 patent does not teach, nor does the Mueller device provide useful plasticity, e.g. energy dissipation, capability at all.

The novel design of the claimed Active Element device successfully satisfies this complex and long sought after engineering goal, allowing desirable deflection levels generally similar to a conventional shear wall system, but additionally providing

[3] In a preferred embodiment metal of the requisite shape and thickness is utilized, but it is obvious to one skilled in the art that a wide range of materials and configurations in many combinations can be employed to produce the claimed force/deflection properties. It shall be further understood that the examples herein are merely exemplary and should not be considered limiting in any manner. Any geometry and combination(s) of materials can be used for the Active Element that generates a useful force versus deflection property when loaded in one or more directions.

dramatically higher energy dissipation as a result. Further, the claimed Active Element employs a unique and different structural means while obtaining unexpected improved properties as compared to the Mueller device.

Please note, it is of significant importance that the Mueller '001 patent uses engineering terms in a manner inconsistent with generally accepted usage in structural design. In addition, the terms as used in the Mueller '001 patent are not consistent with building code considerations or with the technical functionality of the Mueller device. Therefore, to clarify terminology, notes and definitions that are referred to both in the 10/074,684 application and in this declaration are provided at Appendix A.

III. No Plasticity In The Mueller Device

The Mueller Device

The Mueller device includes a head assembly (see, variously 800 in Figs. 7, 8, and 10; 400 in Figs. 11 and 13; and 1410 in Fig. 14). The head assembly typically has a spring and a plate, such as 970 and 910.[4] The head assembly is typically connected from a wall header to a secondary shear system specified in the Mueller patent as being rigid. The Mueller patent states that the head assembly is attached to the rigid A-frame and the rigid metal and composite shear panels (col. 48, lines 39 to col. 50, line 54) (emphasis added). Mueller also states that the rigid shear structures can be mounted with springs. As shown in Figs. 8, 10 and 11, the spring attachment of the rigid panel places an additional spring element in series with the spring element(s) of the head assembly, e.g., springs 970 a, b; 460 a, b, c, d. An anchor assembly anchors the shear assembly to the foundation of the building (See claim 1).

Method of Analysis and Comparison

Although the Mueller Device incorrectly uses common engineering terms, an analysis of the Mueller Device indicates that the Mueller Device can be compared in common terms (see Appendix A) and using accepted engineering modeling methods (See Appendix B). For purposes of this analysis and as a means of showing critical distinguishing characteristics between the claimed Active Element and the Mueller device, "spring/mass/damper" analysis of the Mueller device can be utilized.[5] Appendix B

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[4] The Fig. 14 head assembly does not have a spring at the head assembly 1410, but rather at the anchor assembly 1430.

[5] Applicants note that the Active Element does not incorporate the use of mechanical springs for its effect. Further, Applicants assert that the Active Element functions in a manner more than that of a spring. Applicants also assert that Mueller's springs do not provide significant dissipation or damping. However, spring/mass/damper analysis is a common analytical tool and comparing the disparate Mueller device and Active Element by this methodology highlights critical differences between the two. Other methodologies can be used to differentiate the present claims over the Mueller device and Applicants reserve the right to demonstrate such additional methodologies, as necessary.

contains selected excerpts from SAE Race Car Vehicle Dynamics, a publication that includes a description of spring/mass/damper systems and analysis.

A. Stiffness

Mueller Device: a "hardening" system

For purposes of the analysis, assume that S_2 in the SAE Figures 21.4 & 21.5 (Appendix B) correspond to the spring assemblies 1560 as shown in Mueller Fig 16b, at the lower corner of the rigid A frame or shear panel, and that S_1 correspond to the springs 970a and 970b in the incorrectly characterized "damper" assembly of Fig 10. Note the vertical axis of the graphs is the force applied, and the horizontal axis is the deflection.

The composite spring rate of two spring systems is always less than the stiffest spring (see upper graph Fig 21.5). Note that the total deflection is defined as $X_T= X_1+X_2$ (this holds true for any spring system where both springs are loaded simultaneously).

The lower graph on SAE Fig 21.5 shows what happens when one of the "damper" springs bottoms. Note that when S_1 is fully compressed, or "bottoms", its spring rate goes to infinity, i.e. it becomes rigid and the spring rate of the overall system stiffens (hardens) to that of spring S_2. Also of significant note: when the springs are unloaded, the load-deflection follows the same two sloped lines back down.

This form of analysis is valid for any number of spring components, be it coil springs or "stiff" as opposed to "rigid" structural elements in series, e.g. linked in a common load path. The analysis shows that a series of springs, such as in the Mueller device, produce a force/deflection curve that increases generally linearly (or stiffens or hardens) and the rate increases as the various spring (elastic) elements reach the limits of their travel. At each point corresponding to a limit of travel of a spring (elastic) element, the force/deflection curve changes from a lower slope to a higher slope.[6]

The spring/mass/damper analysis of the Mueller device does not have a lower slope force/deflection curve at higher deflections. Thus, the loads on the structure to which the Mueller device is attached and the loads at the points at which it is anchored continually increase disproportionately as deflection increases. This is known as a "hardening" system, and such a system is detrimental to dissipating energy compared to other alternatives.

Further, the Mueller system has no means to provide significant dissipation of energy, which is of key importance to mitigating earthquake damage to structures. Figure

[6] The mathematics for the series spring case is quite simple. When multiple springs are connected in series, the compliance, or inverse of stiffness, is summed. Thus, the total compliance is $1/K_T = 1/K_1 + 1/K_2 + 1/K_3 +\ldots$ It can be seen that as any spring bottoms out (becomes infinite stiffness), its term is dropped from the equation as it equals zero (1/infinity = 0) and the compliance becomes smaller (or stiffness becomes greater), as shown in the graphic analysis.

1 shows how loading follows the "hardening" load-deflection curve, and unloading follows that same curve back down. This is assured by the usage of springs, which will absorb energy when loaded and merely give it back when unloaded (see Appendix A.I.). The difference between the loading and unloading paths represents energy dissipation, and there is none here.

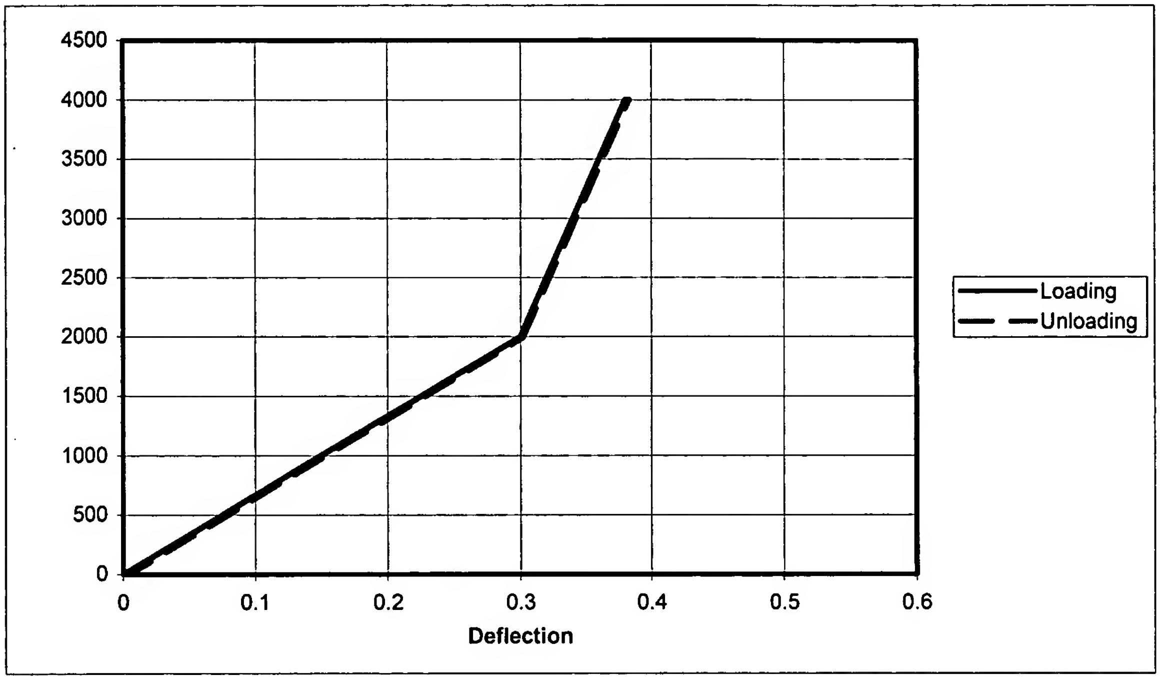

Figure 1. Mueller load-deflection curve
Note: There is no difference between the loading and unloading paths, i.e. energy is absorbed and then given back (elasticity). There is no energy dissipation.

Claimed Active Element: a "softening system

In contrast to the Mueller device, the claimed Active Element produces a force/deflection graph, as shown in Figure 2 below.[7] The Active Element has defined force versus deflection properties that initially is linear (or constant stiffness) up to a selected level of force, and the Active Element will then begin to deform plastically, and the slope of the force/deflection curve will decrease in a controlled (or selected) manner as deflection increases. Thus, the loads on the structure to which the Active Element is attached, and the points at which it is anchored reach a maximum level that remains ideally constant (or increases in a selected, gradual, and controlled manner) as deflection increases. This is known to one skilled in the art as a "softening" system, and such a system is beneficial for dissipating energy. The mechanism of plasticity is used by design in the Active Element to cause the load-deflection curve to reduce in stiffness as load increases, and to provide an

[7] Figure 2 is merely exemplary, and is not to be considered limiting in any manner.

unloading path quite different than the loading path (known as hysteresis). (See Appendices A.II. and C Dissipation Analysis Figures A-C) This provides large energy dissipation capability, proportional to the area between the loading and unloading curves, as can be seen graphically in Figure 2, below.

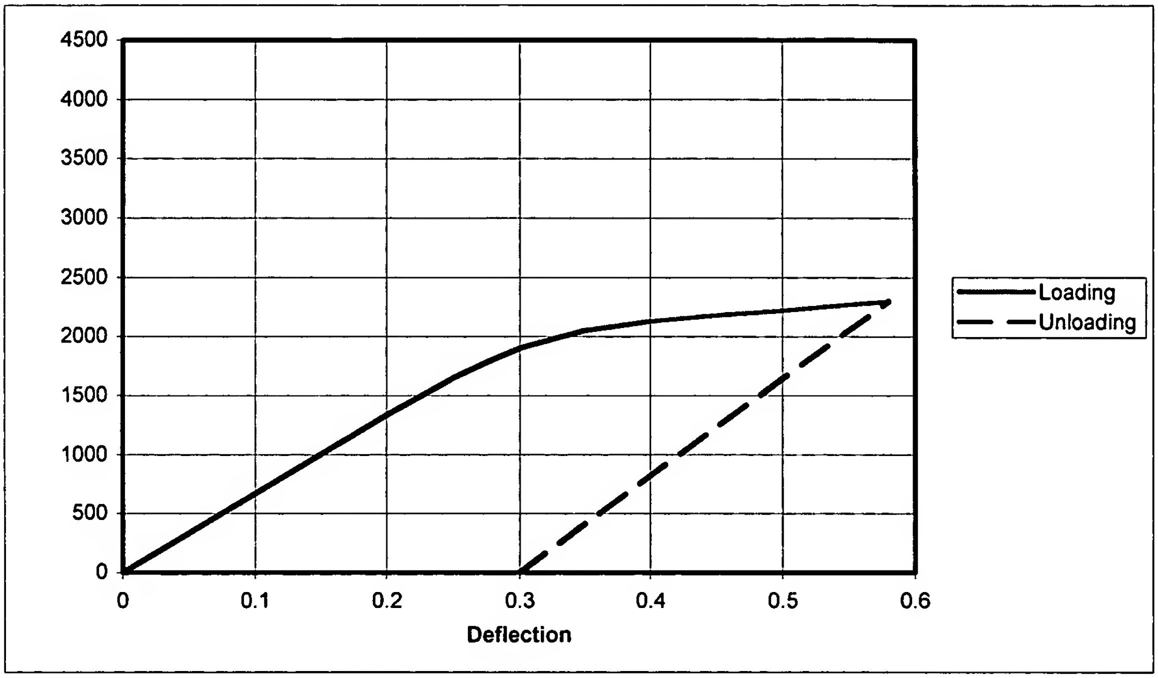

Figure 2. Active Element load-deflection curve
Note: The area between the loading and unloading paths indicates energy dissipation, e.g., via plasticity.

In addition, the selected stiffness of the Active Element can be designed to generally match or complement the properties of the structure to which it is attached. The load-deflection curve can be "tuned" to match the load-deflection curve of a piece of wood framed wall being replaced, for example. Wood framed walls have generally softening load deflection curves and dissipate energy by hysteresis, as the Active Element system does, although the Active Element system adds the desired improvement of significantly more efficient energy dissipation. (See Appendix C: Dissipation Analysis Figures A-C)

Comparing the Mueller device (Figure 1) and the Active Element device (Figure 2), there is no similarity. The Mueller device provides hardening behavior, whereas the Active Element system is designed to provide softening behavior and large energy dissipation via hysteresis. It is critical that energy dissipation is provided for earthquake survivability, because it reduces destructive deflections within a building or portion thereof.

In summary, once the Active Element reaches the selected maximum elastic load, further applied force will result in more deflection, vs. the substantially higher loads of the

Mueller device. This effect is clearly shown in the force/deflection curves in the excerpts from the WJE report[8] (See Appendix C).

B. Forces and Loads

Mueller Device

In the Mueller device, lateral load applied to a wall results in lateral displacement of the top of the wall. The lateral load is resolved into the attachment device (e.g., a single location) and is passed through the attachment device to a rigid shear assembly, producing its own uplift and compressive forces in separate legs of the shear assembly (col. 3, lines 47 et seq.), e.g. overturning moment. Thus, forces input to the Mueller device ultimately are merely removed out of the wall by transfer to the foundation (via direct attachment).

The Mueller device is a point load system, i.e. header "collection" device. It picks up all the shear loads on the wall to which it is attached at a single point at the header where the shear resolves into lateral motion along a single axis, and feeds the full loads into another structure, i.e. the foundation, by means of a separate shear panel or A frame. This means that not only is the incorrectly described "damper head" intended to receive the lateral shear forces only in the horizontal direction, but also the loads on the springs and tie-downs are concentrated and very high, as it must resist all of the resultant movement from shear loads in the wall to which it is attached. (See Appendix E for a discussion of collected wall shear loads and overturning loads).[9]

In the abstract and elsewhere, Mueller describes that springs "dissipate" energy. This is not consistent with generally accepted knowledge of one skilled in the art. (See Appendix A. I.) The Mueller device has no meaningful hysteretic damping. As is well known to one skilled in the art, the hysteresis in the spring systems disclosed by Mueller can be considered to be zero. [10] (See SAE reference Appendix B)

Further, all the embodiments of Mueller only show spring elements in conjunction with rigid assemblies. That is, elements assumed by those skilled in the art to be springs with negligible dissipation or damping, and elements specifically designed to be very rigid (vs. plastic).[11] Further, the example cited by the examiner of Mueller (Figure 8: assembly) depicts an assembly specifically designed to be very rigid (i.e. not plastic in any way), so

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[8] Note especially the WJE report summary (Appendix C) and Fig. 1 (a plain shear wall), Fig. 2 (a plain shear wall with 30"x30" opening), and Figs. 4 & 6 of the application (a shear wall with 30"x30" window opening with Active Elements installed). Also note how the Active Element can be tailored to provide different force/deflection curves as shown in Figs. 4 & 6.

[9] In addition, it is of significant note that the Mueller device actually develops and contributes its own localized overturning moment in the A frame or shear panel, which must then be transferred to the structure to which it is attached.

[10] Note that this also includes Mueller's "compression disks", which are known by those skilled in the art as Belleville springs and as possessing all the general performance characteristics of springs.

[11] See Appendix A.IV.

that the spring element will flex fully and absorb energy (not dissipate energy), as Mueller intends. (col. 20, lines 41-51)

No Mueller embodiments indicate incorporation of significant damping effect, hysteretic or otherwise. In fact, a person of ordinary skill in structural design, upon examining the Mueller '001 patent, is led in an engineering direction entirely different from Applicant's beneficial plastic deformation (dissipation or damping). Note that any material can have some insignificant internal damping or hysteresis under elastic deflection. But to one of ordinary skill, such negligible hysteresis has no beneficial effect in an earthquake and an engineered design cannot use this insignificant internal damping or hysteresis to produce the strong hysteresis and energy dissipation due to plasticity utilized by design in the Active Element device.

In summary, the Mueller device is a load collector that simply transmits loads to the foundation via an added rigid structure and spring system. It does not incorporate designed hysteretic or viscous damping elements, as is shown in Figure 1.

Claimed Active Element

Applicant's Active Element device is a distributive load system, i.e. directly receives shear forces on both the horizontal and vertical axis and can receive and transmit loads from multiple or distributed locations. The Active Element reacts to the local [12] shear force components and transmits them about the periphery of an opening or between adjacent structures, or within a shear panel or membrane. The Active Element can be installed about an opening or on or between discontinuous structural elements, thereby directly absorbing (by elastic deflection) and dissipating (by plastic deformation) energy from all components (horizontal and vertical axis) of shear forces, including the resulting overturning moment (see Figs. 6-10 of the present application). Further, the forces are not reacted to a separate panel assembly or A-frame assembly, nor is direct reception from the header at one end or by direct transfer to the foundation at a second end necessarily required.

The horizontal loads tend to cyclically open or close the non-planar sheet of metal of Applicant's claimed Active Element as shown in the finite element analysis (which leads to plasticity and hysteretic damping); whereas the vertical loads are reacted mostly elastically in the stiff vertical direction of the Active Element. The Active Element device thereby transmits, in a controlled manner, forces in a shear wall, and absorbs and strongly dissipates energy. And this is done in a manner that can substantially match the general load performance of the adjacent structure as is shown in the finite element analysis of Applicant's Figures 9 and 10. This feature provides the valuable function of avoiding stiffness mismatches that can cause local stress failures in the wall structures.

[12] e.g. points about or within the wall at which they are generated.

Mueller Device vs. Claimed Active Element

First, the Mueller device does not limit anchor loads at higher deflections. In fact, the increasing slope of the force/deflection curve of the Mueller device means that anchor loads will detrimentally and disproportionately increase as the deflection increases. For a discussion of this effect, see Appendix E, "Seismic Response of Wood-Frame Construction".[13] In contrast, the Active Element limits anchor loads by producing a softening load deflection curve (See Appendix C). It should be noted that in the WJE report, Fig. 4, (Appendix C) for structures incorporating the claimed Active Element, the peaks of the cyclic force/deflection curves remain at a relatively constant level well beyond the mandated code deflection range.[14]

Second, in contrast to the Mueller device introducing its own overturning moment, it is of significant importance to a building's earthquake survivability that not only does Applicant's Active Element not introduce its own overturning moment, it in fact limits the overturning moment of the shear wall to which it is attached.

Third, shear panels are tested under cyclic load.[15] The Mueller device does not make provision for elastoplastic behavior under cyclic load – the energy is absorbed when loaded and given back when unloaded, thereby providing no means of significant dissipation of energy. In contrast, the Active Element has cyclic elastoplastic behavior as seen in FEA Figs. 11-13 and the WJE tests, which results in large energy dissipation.

Even if one were to allow that the Mueller device and associated structure enters a plastic stage, it cannot deform plastically in a controlled or selected beneficial manner. If it were to enter a plastic phase, it cannot replicate the cyclic performance and force/deflection curves of the Active Element. If one looks at the case of the springs in the Mueller device, the springs become rigid if compressed sufficiently. Even if one were to consider that the supporting building structure around the Mueller device may be sufficiently strong that, at some deflection, the metal of the rigidly compressed spring would actually flow plastically, the free length and all the characteristics of the spring would be irreversibly altered, and the cyclic nature of the load would not be able to reverse the plastic distortion. This detrimental deformation is in sharp contrast to the repeatable designed cyclic elastoplastic response of the claimed Active Element.

[13] Note especially the higher overturning loads on narrow shear panels, such as would correspond to the "A" Frame and shear panels incorporating the Mueller device. Overturning moments are proportional to height/width ratio.

[14] This range is defined in California Building Code as a maximum of 0.025 of the panel height, and shall be calculated based on the building structure having a fundamental period of less than 0.5 sec.

[15] Shear panels in the building industry are tested under AC130 specifications of the ICBO (Acceptance Criteria for Prefabricated Wood Shear Panels AC130 (Effective 1 July 2004)) (Appendix F), which requires that the structure maintain specified resistance characteristic under cyclic displacement and number of cycles, selected to provide representative earthquake loads such as a shear wall might experience.

Likewise, once any of the other structures in Mueller, which he defines as "rigid" such as the "A" frame, shear panels or other metal brackets, distort plastically, the reverse cycle simply cannot restore the original strength, configuration and rigidity of the component. This non-restorable loss of properties after what would be considered plastic failure is well known to one of ordinary skill in the art of structural design. It is the novel configuration of the Active Element that allows repetitive plastic distortion, such as may result from earthquake and other forces applied to the building (See Figs. 11-13 of application).

Moreover, throughout the Mueller 001 patent Mueller designs to avoid plastic deformation, as described at, for example, col. 8, line 26 and col. 10, lines 33-34. Mueller specifically desires rigidity of the plate system, as stated many times in the Specification (col. 20, lines 41-51). Plasticity (a form of deformation) is nearly the opposite of rigidity (does not deform during motion). Beneficial plasticity, and the resulting strong hysteresis and energy dissipation, is therefore precluded by Mueller's claimed device, and is certainly not an obvious extension.

Finally, the elastoplastic nature of Applicant's Active Element, whereby it behaves elastically under a first loading, and plastically as a significant hysteretic damper under a second and higher loading, and in some embodiments, a second elastic manner under a third and higher loading, is discussed in the present application and demonstrated in the FEA's illustrated in Applicant's Figures 12-14 and the hysteresis loops of the WJE report (Appendix C).

Therefore, there is no single element, or combination or sum of elements in the Mueller device that anticipates or will produce the claimed cyclic elastoplastic characteristics and properties of Applicant's Active Element.

IV. Criticality of Claimed Properties and Unexpected Improvement

As is illustrated in Figure 2, at a determined load the Active Element will begin to deform plastically, and the slope of the force/deflection curve will decrease in a selected, gradual, and controlled manner. This unexpected improvement of claimed properties is what contributes to the ability of structures incorporating the Active Element to substantially match the general characteristics of a standard code shear wall (see, Figs. 6-11 of application), as well as greatly increase energy dissipation, optimize building response to shear loads by minimizing the concentration of vertical forces caused by overturning moment on shear walls, providing efficient load sharing[16] between discontinuous structural elements[17] of a shear wall, control and limit uplift forces on shear panel anchors, and other advantages. These important functions are not present in the Mueller device.

[16] See Appendix A.VI.
[17] See Appendix A.VII.

In addition to the analysis and discussion in this declaration, the specification of the present application contains several examples of criticality with respect to the claimed force versus deflection properties.

Improvement In Performance

The specification at paragraph [0070] discusses the performance of the typical shear wall with an opening. It states that "the load resisting capacity of the shear wall 200 is reduced by a factor of almost four." The specification also states that, "as shown in FIG. 7, the opening also produces extreme concentration of stresses in the corners of the opening as can be evidenced by the red stress pattern indicators 280.

In comparison, paragraph [0073] describes that the force-resisting member including the active element is designed to implement the desired known force versus deflection properties of the active element. This allows the engineer to select and design the proper active element that will provide load sharing across a discontinuity formed in the shear wall such that the shear wall including the force-resisting member performs substantially as if no opening existed in the shear wall. This allows an engineer to "tune" the building such that all of the shear walls behave in a similar manner so that a force concentration is not created in any portion of the building that could lead to failure of the building. Further and as shown in FIG. 9, the modeled shear wall including a force-resisting device 100 designed for the size opening in this size and configuration of shear panel, achieves two inches of drift in the shear wall 200 when 10,705 lb of force is applied. The specification continues:

> Comparing this to FIGS. 6 and 7 it can be seen that the shear wall including the opening 240 and the force-resisting device 100 behaves substantially like the shear wall 200 as shown in FIG. 6 with no opening. That is, with the force-resisting device 100 disposed about the periphery of the opening the shear wall including the opening functions in nearly the same manner as that of a solid shear wall, i.e. it transmits substantially similar shear force for a given deflection, and the stresses in the panel are not concentrated and do not result in premature failure. This can be better understood with reference to the graph shown in FIG. 10.

In paragraph [0076], FIG. 10 is discussed. FIG. 10 shows a graph illustrating the performance of the shear wall 200 shown in FIGS. 6-9. As shown in the graph in FIG. 10, the present invention, when disposed about an opening formed in a solid shear wall, "replaces all of the lost stiffness and dissipation capacity of the solid panel." FIG. 10 shows three separate load versus deflection characteristic lines. The first line 400 illustrates the load versus deflection characteristics of the solid shear wall of FIG. 6, and the second line 500 illustrates the load versus deflection characteristics of the shear wall

including a 30 inch by 30 inch window opening as illustrated in FIG. 7. As can be seen by the difference between line 400 and line 500, the creation of the opening within the solid shear wall drastically reduces the load bearing capacity of the shear wall. Referring now to line 600, there is shown the load versus deflection characteristics of the shear wall including the 30x30 inch opening and the force-resisting device 100 in accordance with the present invention disposed about the periphery of the opening. As shown in the graph of FIG. 10, the present invention restores the shear capacity of the shear wall such that the shear wall including the present invention and a 30x30 inch opening formed therein performs substantially similar to a solid shear wall. Thus, it can be seen that the force-resisting device is configured to resist forces and reduce stresses and replace stiffness, dissipation, and strength to the structure such that the structure behaves substantially as if a discontinuous structural element has not been formed therein.

V. Mechanical and Structural Differences

The Mueller device is a composite assembly, comprising springs and rigid structures, and is a single point "collective load system" that operates within an elastic range of operation. The composite Mueller device is limited to attachment to the upper portion of a wall (i.e. header) at one end and the foundation at a second end (col. 51, lines 14 et seq.). Mueller comprises a collection device attached to an upper portion of a wall that collects force on one axis from the structure to which the Mueller device is attached. The collection device, comprising generally a metal box-like structure, is attached by a single point to one or more coil or disc spring elements arrayed to resist horizontal motion by compression and extension of multiple springs. These springs are attached by means of another rigid metal structure which is mounted on a rigid device such as an "A" frame or shear panel, that is then mounted to a foundation to resist the collected forces fed through the Mueller device.

Utilizing an entirely different structural means, Applicant's Active Element is a non-planar sheet metal "distributive load system", which operates beneficially within elastic and plastic ranges of operation. The Active Element when installed in a structure generally extends along the edges or boundary between two discontinuous structural elements or about an opening such that all the components of the shear forces are fed into the Active Element along the entire discontinuity between structural elements or a portion thereof, or about an opening or portion thereof. The shear forces are fed directly into the Active Element along the length of the structure to which it is attached and result in beneficial deformation of the non-planar portion of the sheet metal of the Active Element under cyclic loads as disclosed.

Further, the Active Element does not incorporate the use of mechanical springs, nor an integrated panel assembly (col. 4, lines 48 et seq.) or A-frame assembly (col. 3, lines 11 et seq.). Also, neither interconnecting the upper portion of the wall at one end to the

foundation at a second end or direct attachment to the foundation is required [18], as is the case in the Mueller device.

The Active Element directly resists the vertical and horizontal components, and the resulting overturning moment, of shear forces. In a preferred embodiment, this is accomplished by means of a single piece of formed sheet metal that, by means of its selected elastoplastic properties, not only provides selected force/deflection characteristics, but provides hysteretic damping to dissipate energy and thereby reduce deflection in the structure to which it is attached. No single element or combination of elements in Mueller simultaneously provides these capabilities, nor are means provided for Mueller to resist forces which are directly input on more than one axis or from multiple or distributed locations.

In summary, the Mueller device and the claimed Active Element employ entirely different mechanical and structural means to protect a building from destructive elements. The manner in which these mechanical and structural differences relate to the structure in which the respective devices are installed is discussed and compared in Appendix G.

VI. Conclusion.

Detailed evidence is presented in this Declaration in the areas of Applicant's claimed force versus deflection properties, e.g., stiffness, forces and loads, and mechanical and structural differences. It has been shown there is no embodiment in the Mueller '001 patent that provides functionality that replicates Applicant's Active Element device in these areas.

A shear wall with the Active Element device supports load at larger deflections than a plain shear wall (with or without openings), as opposed to the Mueller device. The Active Element device successfully solves a long sought after problem in the industry by allowing walls of any length with any number of openings to have generally uniform load carrying, resulting in reduced stress concentrations, versus the Mueller device, which actually introduces its own stress concentrations. The Active Element's claimed cyclic elastoplastic properties provide unexpected performance improvements that reduce localized stresses leading to less damage for a given earthquake or hurricane level and forestalled collapse at higher loads.

[18] This is not to be considered limiting in any manner. Applicant's device may be installed in any number of configurations, thereby transmitting forces, and absorbing and dissipating energy across discontinuous structural elements.

TERMINOLOGY/CONCEPTS

Discussion: Mueller Patent's Incorrect Usage of Terminology

Terms such as dissipation and ductile are utilized in Mueller '001 patent to incorrectly describe embodiments that demonstrate no capacity to provide useful dissipation or ductility. The meanings of these words, to one of ordinary skill in the art, are at odds with the elements of the Mueller device.

For example, there is no description whatsoever of the use of plasticity and hysteresis to achieve energy dissipation. The term "dissipation" is misused to describe what actually is the temporary absorption of energy by springs (See Abstract). Mueller uses "ductile" (a material that can deform plastically without failure) to describe simple spring action, or the ability to allow some elastic deflection (col. 35, lines 15-28) (col. 14, lines 53-56)..

Moreover, in every instance, Mueller describes "forces" being absorbed. This too is incorrect. To one of ordinary skill in the art, forces are not absorbed - *energy* is.

A.I. Springs Absorb vs. Dissipate

Mueller repeatedly states that springs "dissipate" "forces". This is not correct. A spring absorbs *energy* when deflected, and releases it when the forces causing the spring to deflect are released. In other words, a spring temporarily stores, but does not dissipate energy. (See, for example, Appendix B) As stated in Appendix B, a "spring is assumed to dissipate no energy". Thus, the spring can be said to have essentially no meaningful "hysteresis". And again, forces are not absorbed - energy is.

> Elasticity can be defined as "a property of a material by virtue of which deformation caused by stress disappears upon removal of the stress" (ASM Metals Handbook, Desk Edition, 2nd Ed., Ed. J.R. Davis, Materials Park, OH: ASM International (1998)).

A.II. Hysteresis

Hysteresis manifests itself as a difference between loading and unloading load-deflection curves on a subject piece of hardware. The specific internal material mechanisms that cause this are complex, involving mechanical or magnetic molecular interaction, metal crystal interaction, or macroscopic plasticity or permanent deformation (which generates large hysteresis). In all cases, energy is ultimately dissipated by irreversible heat generation within the material. The energy dissipated is proportional to the area between the loading and unloading curves.

A.III. Stiffness and Springs

The importance of taking into account the spring energy is shown by the portions of the California Building Code section attached, wherein it clearly states that the design of the structure must take into account the "stiffness" or periodicity (frequency) of the overall structure.

(see Appendix C ...CBC Sections 1630.10.2 & 3 and Findings). It will be appreciated that the release of energy from Mueller's springs under cyclic load would have an appreciable effect on the required code standards of stiffness. According to the code, the release of energy of the Mueller system once the load compressing the springs is released, will be transmitted back into the structure and would in certain cases adversely effect the periodicity of the building to which it is attached. Further, it is important to account for the characteristics of the structure to which a spring is attached. Unlike the Active Element system (which generally matches the structural characteristics of the structure to which it is attached), the Mueller spring system "pushes back" as the load cycle reverses. If not calculated based on the stiffness of the building (which Mueller does not teach), the Mueller springs could actually cause destructive resonance.

Stiffness, which by definition allows for the temporary storage (not dissipation of energy) governs, along with the mass, the natural frequency of vibration of a structure. During vibration, spring potential energy and mass kinetic energy are exchanged continuously, without loss, if there are no dissipation or damping mechanisms present. A "spring" is a mechanical device with "stiffness".

Stiffness implies a static relationship between deflection and force. The load-deflection curve of a spring has essentially equal loading and unloading parts ("static" relationship). In contrast, damping implies a relationship between velocity and force, or alternatively a non-static relationship between deflection and force, i.e. hysteresis.

Note that for a spring to be effective in storing energy, the rest of the system it is in series with must be substantially stiffer than the spring, or "rigid". One must ensure that deflection occurs largely across the spring, not across the other parts. For example, if a spring of stiffness K is in series with a structure of stiffness 10K, then the spring will sustain 91% of the total deflection. But if a spring of stiffness K is in series with a structure of stiffness K, then the spring will sustain only 50% of the total deflection.

A.IV. Rigid Body vs. Plasticity

Mueller repeatedly refers to the structures that support the Mueller device springs as rigid and rigidly engaged (col. 20, lines 41-51). By designing for rigidity one skilled in the art desires no plastic deformation. Again, rigidity and plasticity are nearly opposites. For purposes of accurate comparison, the following definitions are provided:

> "A rigid body is one that does not deform during its motion. The distance between any two points in the rigid body remains fixed . . ." (definition of a rigid structure - University of Winnipeg)
>
> Mechanical engineering definitions generally refer to rigidity as the quality or state of resisting change in form.
>
> Whereas:
> "Plasticity can be defined as non recoverable deformation beyond the point of yielding."

(definition of plasticity - University of Washington)

Mechanical engineering definitions generally refer to plasticity as "permanent deformation".

A.V. Friction

Friction is the interaction between two surfaces that sustains tangential force opposing motion. This can occur when the surfaces are sliding against each other (dynamic friction) or when they are in contact before sliding (static friction). The maximum friction tangential force F that can be sustained by two surfaces is generally related to normal, or compression force N between the surfaces by F=kN, where k is the friction coefficient, which may or may not be a constant, and is generally much less than 1.0 for metals. Therefore, to sustain large friction forces, there must be much larger normal forces.

The incidental friction Mueller *presupposes* may occur is not demonstrated to be of any consequential utility (Mueller 001 patent provides no supporting data). If indeed it would randomly occur as described, the friction created would be inconsequential, and as such would produce no beneficial effect in an earthquake. Assuming a reasonable friction coefficient for metal on metal and the typically large earthquake shear force per lbf, which would need to be carried fully or at least mostly by friction in order to provide a usable benefit; the required large interfacial "normal forces" between the sliding surfaces would be far beyond the capacity of the incidental friction described by Mueller, and therefore are not present in the Mueller device.

If one were to provide useful dissipation, the Mueller device would be required to incorporate components specifically designed to be pre-loaded, wherein the normal force (i.e. contact force exerted between surfaces and perpendicular to the surface) pushing would be sufficient to obtain the required large friction force to resist the very substantial loading that occurs during earthquake events.

Additionally and of deciding significance, it would be required that these components be in the direct load path of the applied forces. This is simply not the case with the Mueller device. Thus, the Mueller device incorporates no meaningful friction energy dissipation elements.

A.VI. Load Sharing

"Load sharing" shall be understood to define the carrying of a total load by some division among more than one load-bearing element. For example, parallel load bearing elements carry load in proportion to their stiffness, while series load bearing elements carry full load (i.e., do not share load).

A.VII. Discontinuous Structural Element

"Discontinuous structural element" is defined as any load bearing structure or portion of load bearing structure that has some feature within it that makes the structure's force transmitting,

stiffness (absorbing), dissipating, or strength characteristics non-uniform, and results in a change of load sharing within the structure, influences the proportion of load shared by the structure relative to adjacent structures, or causes stress concentrations in the structure. Examples of features that cause discontinuous structural elements are door and window openings, localized overly stiffened structural elements, coupled structural elements with different stiffness properties, asymmetrical building configurations, locations in a structure where relative movement of adjacent parts may occur during a loading event, or other similar features.

METHODOLOGY

B.I. Spring/Mass/Damper Systems

Spring/mass/damper system analysis is important in engineering as many devices can be analyzed on this basis, ranging from automotive suspensions, where the shock absorber is the damper, to hydraulic screen door springs, where a damper is used to control the rate of closure of the door.

Generally, spring/mass/damper systems consist of a mass, m, whose motion under an applied force, F, is desired. The forces being resisted are the mass's inertial reaction force, -ma, (Mass x acceleration as per Newton's second law), a spring force, $F_k(x)$ (generally dependent on deflection x), and a viscous damper force $F_c(x,v)$ (generally dependent on deflection x and velocity v), which are mathematically related as:

$$F + F_k + F_c = ma$$

An example of this system is shown in Figure B-1:

234 *Race Car Vehicle Dynamics*

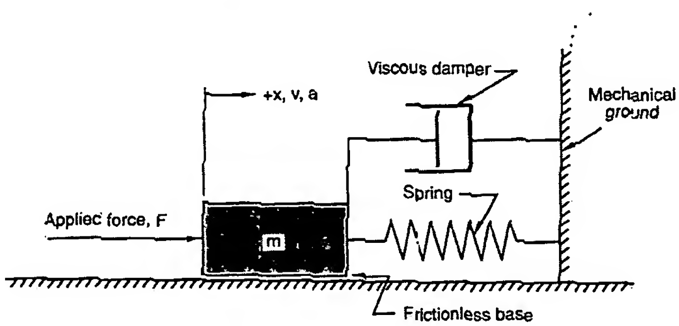

***Figure 6.1** Spring-mass-damper system.*

FIGURE B-1 – Spring/Mass/Damper System Modeling (from SAE Race Car Vehicle Dynamics (p. 234)

Since acceleration and velocity are zero in the steady-state, inertial reaction and damping forces are also zero.

Dynamics

The dynamics of the SMD system are far more interesting than its statics. There are two important parameters that completely define the dynamics of the SMD system: these are its *undamped natural frequency* and its *damping ratio.*

Undamped Natural Frequency

The undamped natural frequency, ω, is given by the expression

$$\omega_n = \sqrt{K'/m}\ \text{, in radians/sec.} \tag{6.2}$$

(divide by 2π or 6.28 to get Hz or "cycles per second")

The undamped natural frequency, usually shortened to "natural frequency," is the frequency at which the mass will oscillate about the zero reference if the mass is pushed down (or pulled up) and then let go. Theoretically, the oscillation will go on indefinitely since there is nothing to dissipate the original energy stored in the spring at its initial deflection (the spring is assumed to dissipate no energy). In the above example (F_1 = 200 lb., K' = 50 lb./in., x_1 = 4 in.) the natural frequency is:

$$\omega_n = \sqrt{50\ \text{lb./in.}\Big/\Big[200\ \text{lb}\Big/\big(32.2\times 12\ \text{in./sec.}^2\big)\Big]} = \sqrt{96.6/\text{sec.}^2}$$
$$= 9.83\ \text{rad/sec.} = 1.57\ \text{Hz}$$

Note: 32.2 is the acceleration due to gravity in ft./sec.^{2}; it must be multiplied by 12 to work in in./sec.^{2}

Since C = 0, the natural frequency is a function only of the mass and the spring rate. As damping is added, frequency (ω_n) tends to reduce with increased C (that is, if damping is light and oscillatory behavior is occurring).

Damping Ratio

The damping ratio is a convenient mathematical tool that shows the influence of the damping constant, C, on transient response. In the previous section the mass was pushed downward and then let go. Because the damping was zero (C = 0) the mass oscillated about its zero reference value. With nonzero damping the transient that takes place, in

x, between the time that the force is removed and the mass comes to rest, at x = 0, will vary in accordance with the damping ratio, ζ; it is given by

$$\zeta = \frac{1}{2}\left(\frac{C}{m\omega_n}\right), \text{ dimensionless} \tag{6.3}$$

If Eq. (6.2) is inserted in Eq. (6.3),

$$\zeta = \frac{1}{2}\left(\frac{C}{\sqrt{K'm}}\right) \tag{6.4}$$

Note that the ζ is directly proportional to C. This equation can be solved for C and used in reverse, if a ζ is known (or desired):

$$C = \zeta \times 2 \times \sqrt{K'm} \tag{6.5}$$

The ζ is useful because its value reveals the following transient characteristics:

(a) If $\zeta = 0$ This results when C = 0. As noted above the mass oscillates indefinitely about the zero reference. In real systems there is always some form of energy dissipation so that, in time, x = 0 is reached.

(b) If $\zeta < 1$ The system is said to be *underdamped*; it will oscillate about the zero reference but with a decreasing amplitude and eventually reach steady-state at x = 0.

(c) If $\zeta = 1$ The system is said to be *critically damped*; the mass will return to x = 0 smoothly, without under/overshoot. If we set Eq. (6.4) equal to 1.0 and solve for C we find that the damping constant needed for critical damping is

$$C = 2\sqrt{K'm}\text{, lb./in./sec.}$$

(d) If $\zeta > 1$ The system is said to be *overdamped*; the mass returns smoothly to x = 0 but more slowly than the critically damped case.

All four of these cases are shown in Figure 6.3.

In all of the above we have concentrated on rectilinear systems. The theory for rotational (torsional) systems is identical, except that angular displacement is involved and the spring-mass-damper units are different (the units of ω_n and ζ are unchanged). The analogous parameters in the two kinds of motion are shown in Table 6.1.

21.3 Coil Springs in Series and Parallel

There are a number of ways in which springs can be used in different installations to produce a composite rate. Two of the most common combinations are springs in *series* and in *parallel*.

Two Springs in Series

Two coil springs, with rates S_1 and S_2, are said to be in series if their centerlines coincide, as in Figure 21.4.

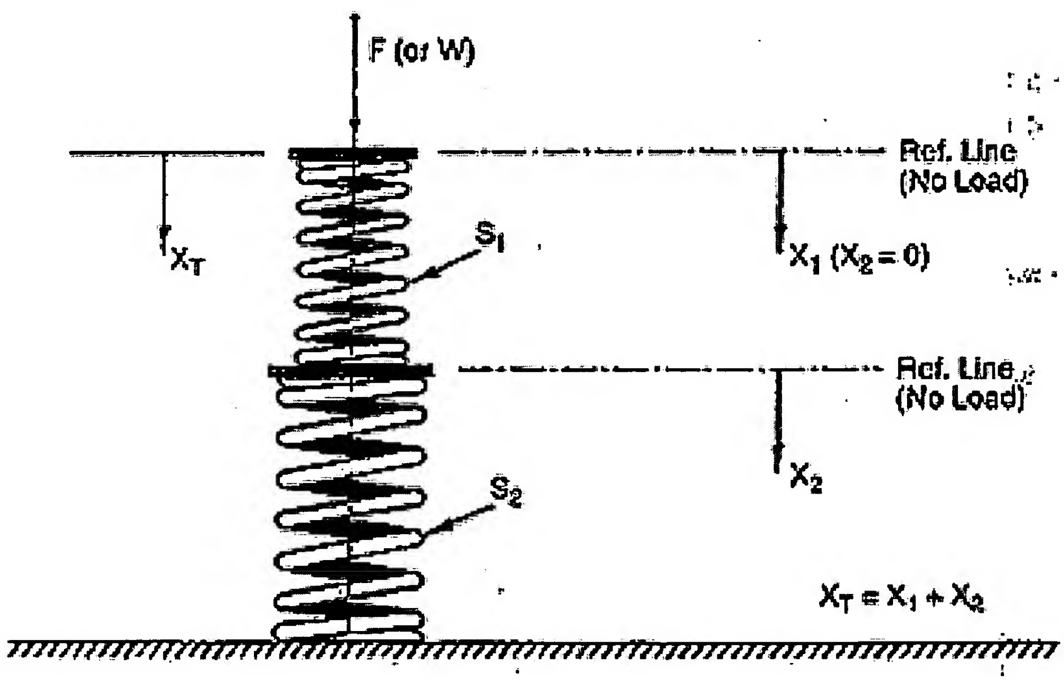

Figure 21.4 Springs in series.

By considering the deflections of each of the springs under the load, F, and adding them, it can be shown that the composite spring rate, S, is

$$S = S_1 S_2 / (S_1 + S_2)\text{ , lb./in.} \tag{21.16}$$

This is analogous in electronics to the resistance of two resistors in parallel and, as in that case, the combined S is always smaller than the lower of the two S's.

If, in the above case, neither spring bottoms out (is not forced to its closed length) over the operating range of X_T, the composite rate is given by Eq. (21.16) and is linear (provided that S_1 and S_2 are linear). On the other hand, if either S_1 or S_2 bottoms out, the composite rate then becomes that of the other spring. Although this behavior can be

shown analytically it is really more easily seen by going to the spring load-deflection plots, as in Figure 21.5.

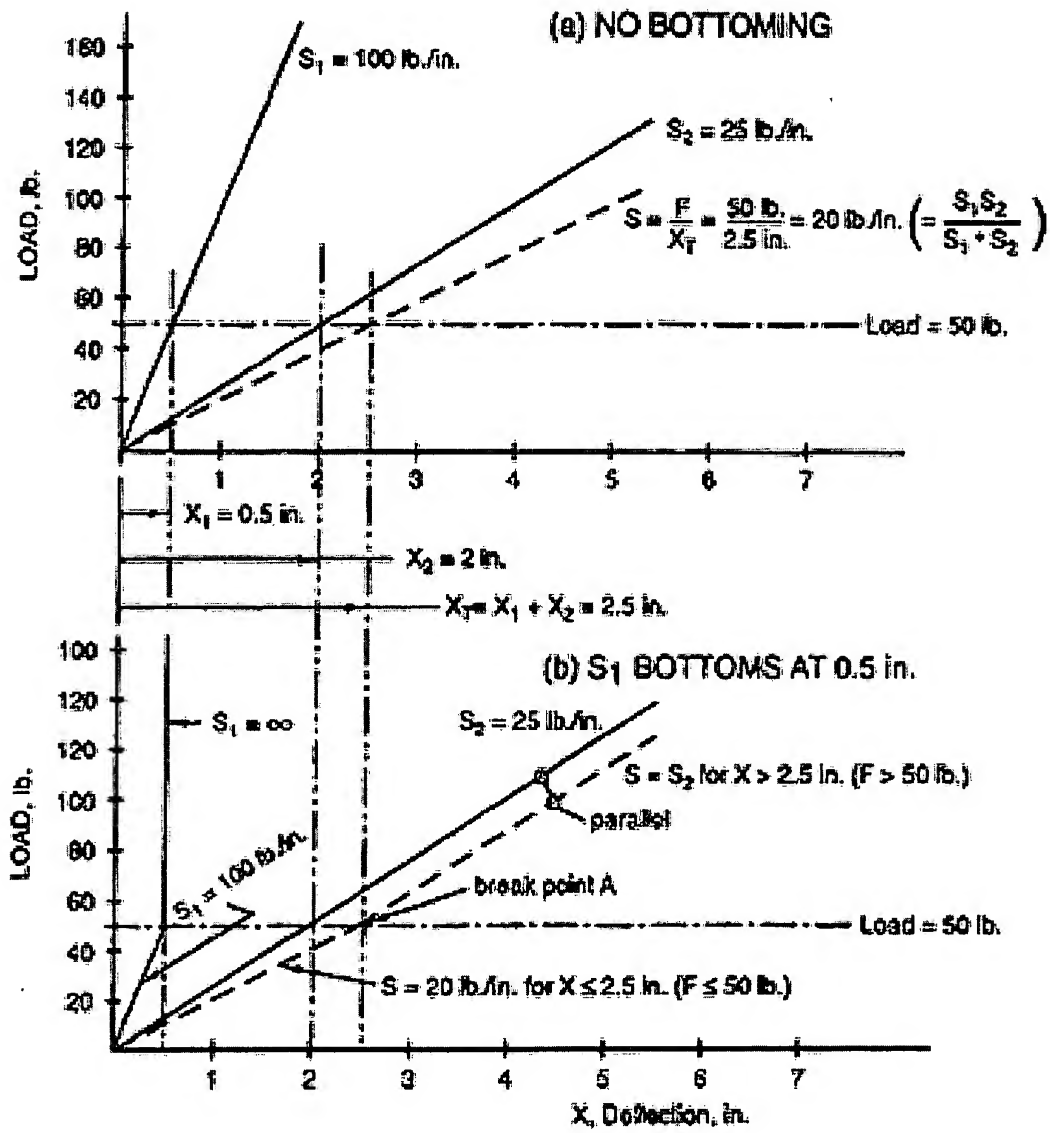

Figure 21.5 Two springs in series, (a) no bottoming and (b) one bottoming.

In part (a), in which no bottoming occurs, the composite spring rate (for any load—in this case 50 lb.) is obtained graphically from the plots as 20 lb./in., which is the answer that Eq. (21.16) gives. In part (b) the stiffer (upper) spring, S_1, bottoms out at $X_1 = 0.5$ in. of deflection (at 50 lb.). At that point the total deflection, X_T (= $X_1 + X_2$), is 2.5 in., and from that point onward the combination has an S equal to S_2.

The above illustration is particular, i.e., specific rates are used. In the more general case the following procedure can be used to find the composite rate. Referring to Figure 21.6, the steps are:

WISS, JANNEY, ELSTNER LAB TESTS - EI-LAND EPE SYSTEM

(Dr. Rory Davis, CEC, 07-05-02)

LOAD-DEFLECTION SUMMARY (ANALYSIS)

Openings in walls drastically degrade the load capacity of wood-sheathed walls. Looking at wall top load-deflection for cyclic loading, Figure 2 shows the great degradation of a centered 30"x30" opening in a 4x8 ft wall segment, compared to a solid wall in Figure 1.

Ei-Land's EPE system, when applied to openings, substantially restores the load capacity of the wall as if there were no opening. The plain solid wall data of Figure 3 is almost exactly reproduced by a wall with an EPE system on an opening of Figure 4.

Figures 1 through 4 depict data from 2x4 side stud walls. For 4x4 side studs, Figure 6 illustrates how load capacity is restored to a wall containing an opening, Figure 5.

Once the construction and material properties of a wall with an opening(s) are known reasonably well, an EPE system can be designed around the opening to substantially restore the load-deflection characteristics of the wall to that of a solid wall.

The EPE system applied naturally reduces the tendency of the wall to fail around the opening and applicable design minimizes damage to the wall compared to an unprotected wall. A wall with the EPE system supports load at larger deflections than a plain wall with or without openings.

The EPE system allows walls of any length with any number of openings to have uniform load carrying, resulting in reduced stress concentrations compared to other non-uniform systems. The reduced localized stresses lead to less damage for a given earthquake or hurricane level and forestalled collapse at higher loads.

Note the "hardening" characteristic of wall load-deflection curves, i.e. load rises faster than deflection. This is primarily due to (the wall's) nail slip behavior, where nails are loosened at low deflections but tighten up at higher limits of deflection. This occurs with or without the EPE system, but the EPE is designed to reduce the hardening effect. Less hardening is better for maximum energy dissipation, given the same load capacity, and "softening" is (beneficial). The EPE system operates primarily in softening mode, thereby countering the nail slip hardening. This is illustrated by the data of Figure 6, where a greater softening behavior design was used compared to Figure 4, and the rise rate of the load is less pronounced. Also, in the event that excessive panel failure leaves the EPE carrying the entire load, the behavior will be softening, which increases energy dissipation and forestalls collapse.

The EPE system behavior can be further optimized by producing walls with sheathing coordinated with the EPE system design, i.e. walls with freedom to choose sheathing material and thickness can have even better performance than by designing an EPE alone. Nail slip behavior and design coordination with it is required for best EPE optimization.

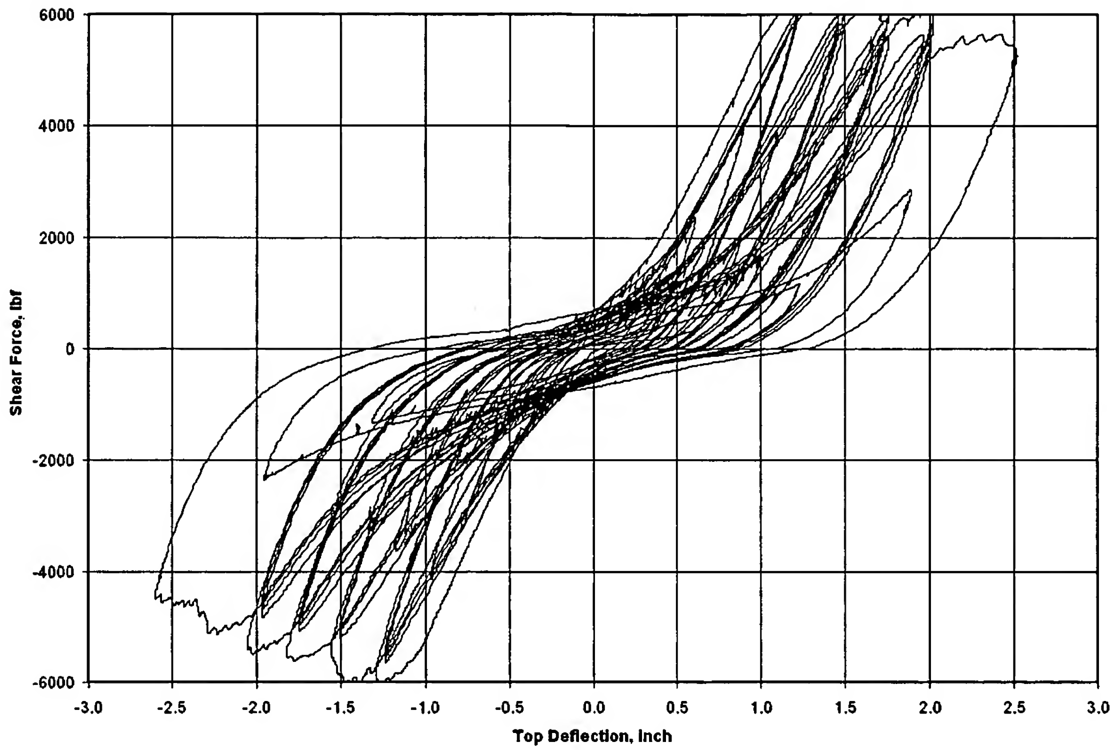

Figure 1. Plain OSB 2x4 Wall

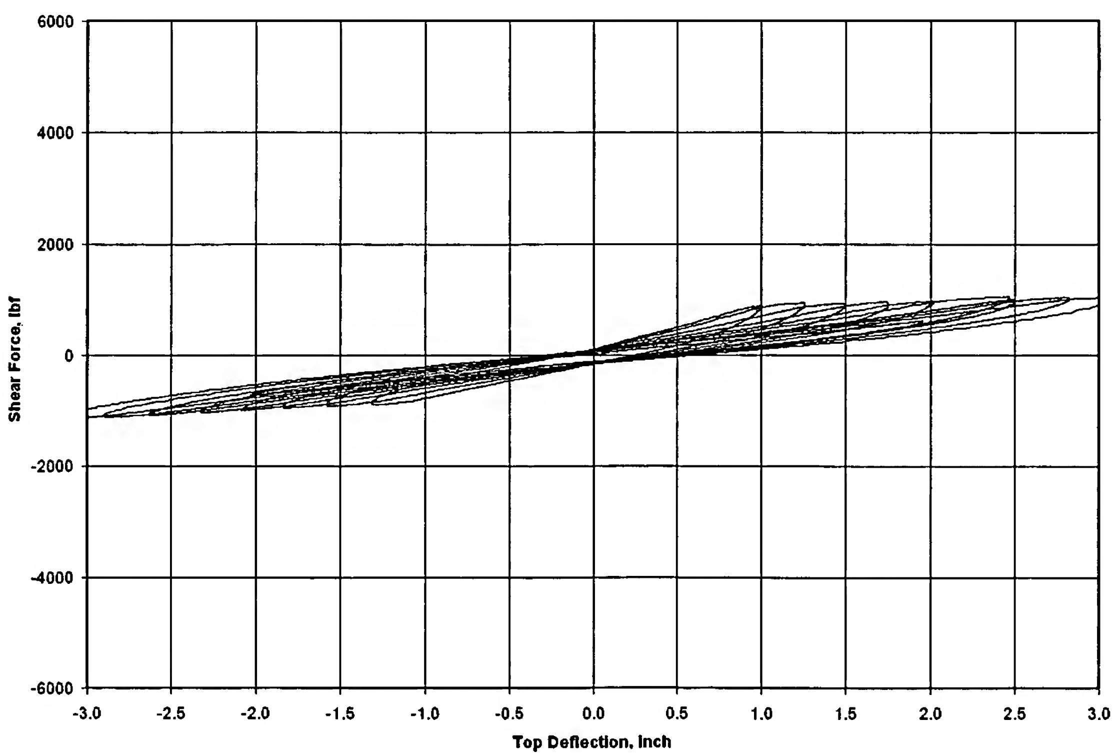

Figure 2. Plain OSB 2x4 Wall with 30x30" window; no window framing

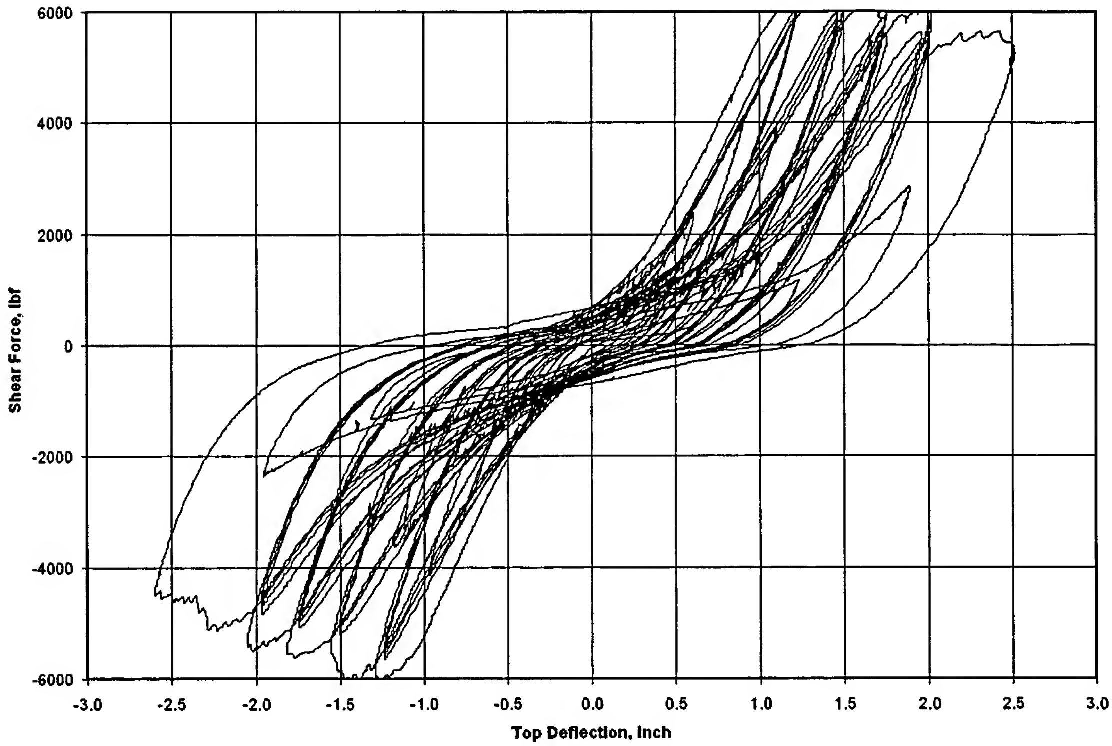

Figure 3. Plain OSB 2x4 Wall (repeated)

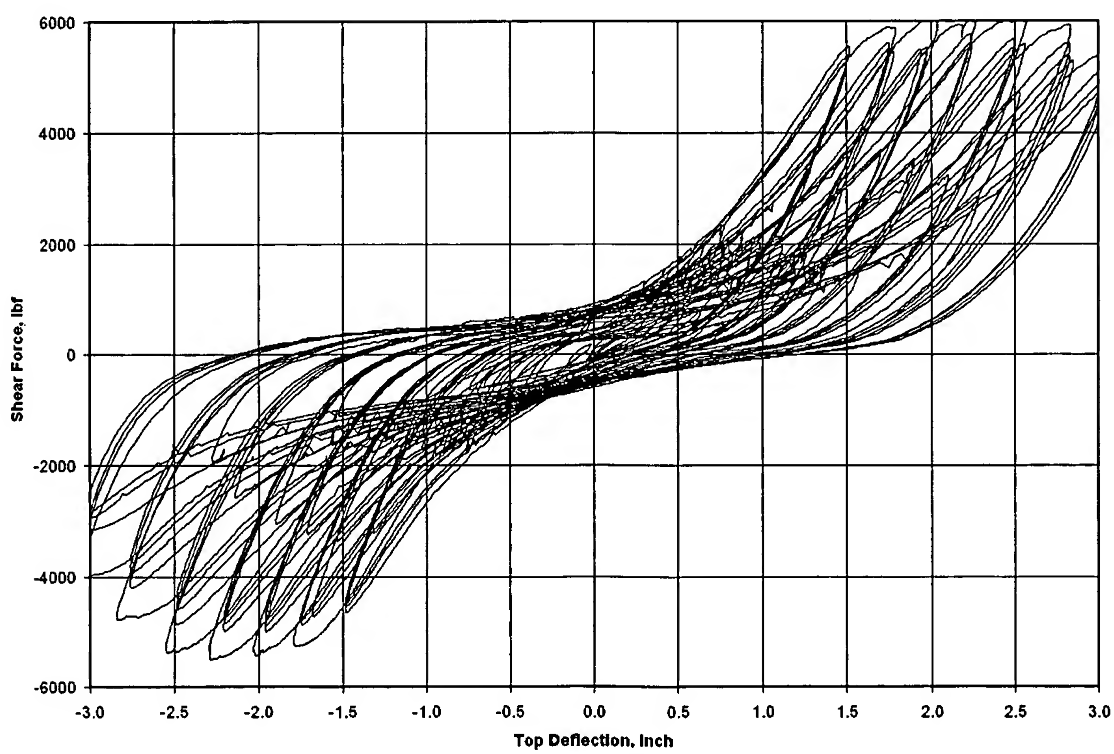

Figure 4. OSB 2x4 Wall with 30x30" window; EPE System

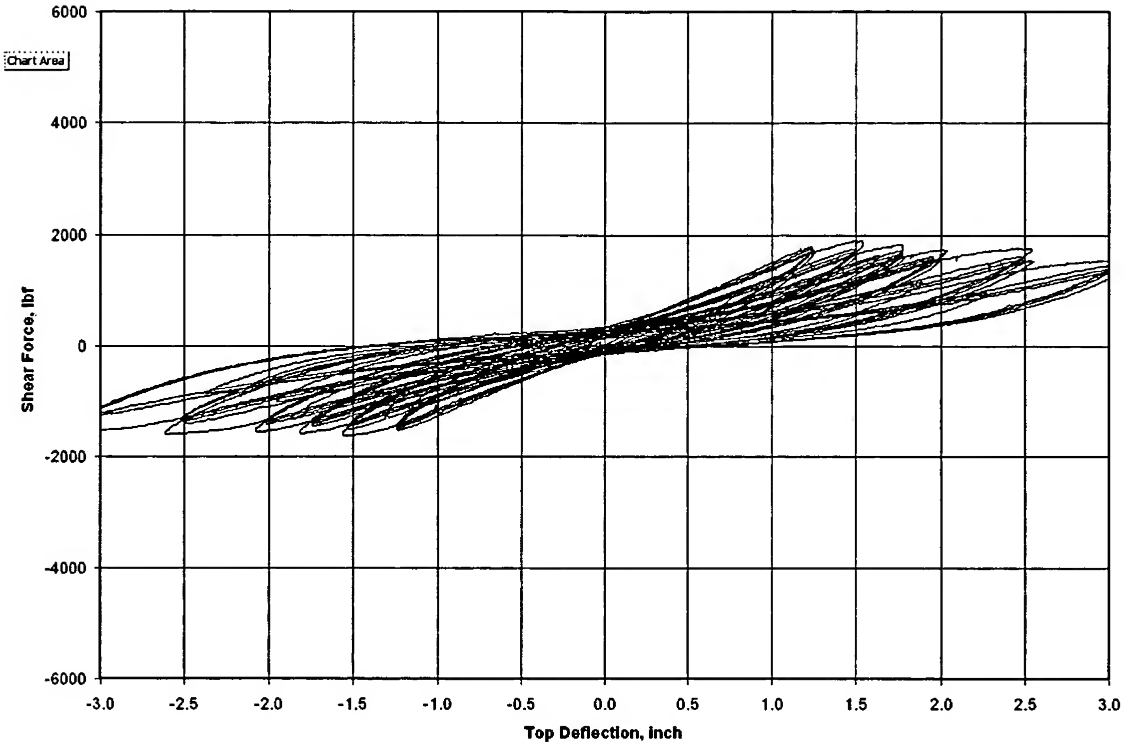

Figure 5. Plain OSB 4x4 Wall with 30x30" window; no window framing

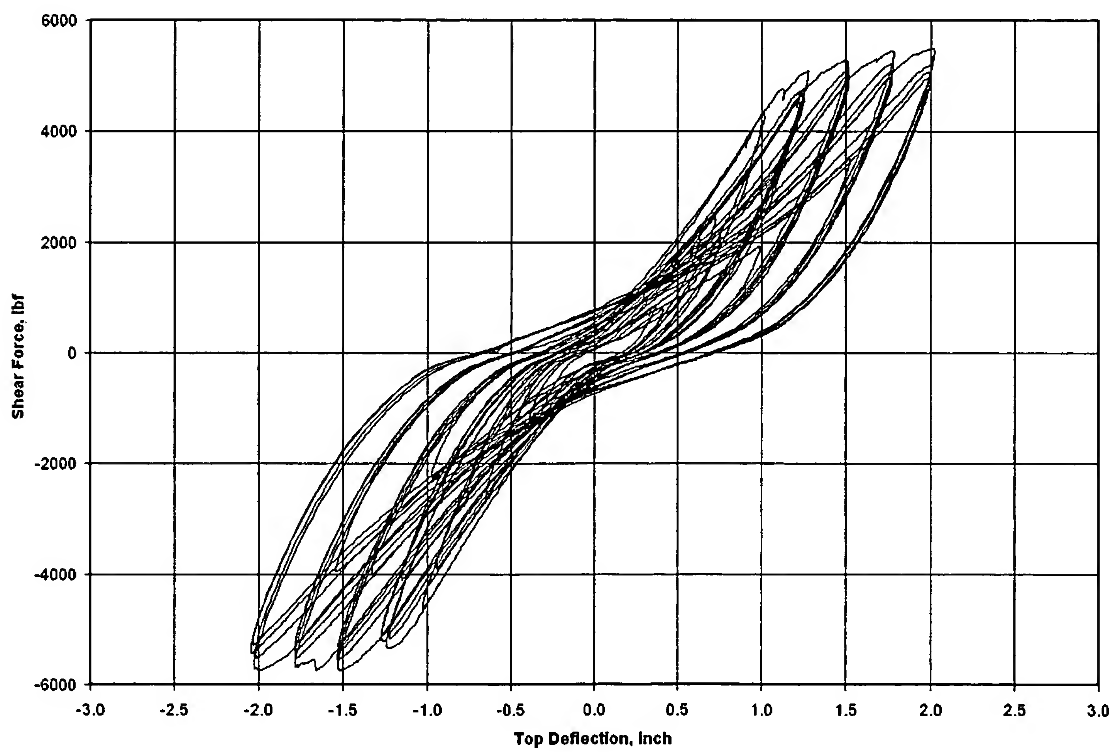

Figure 6. OSB 4x4 Wall with 30x30" window; EPE System

DISSIPATION PER CYCLE ANALYSIS

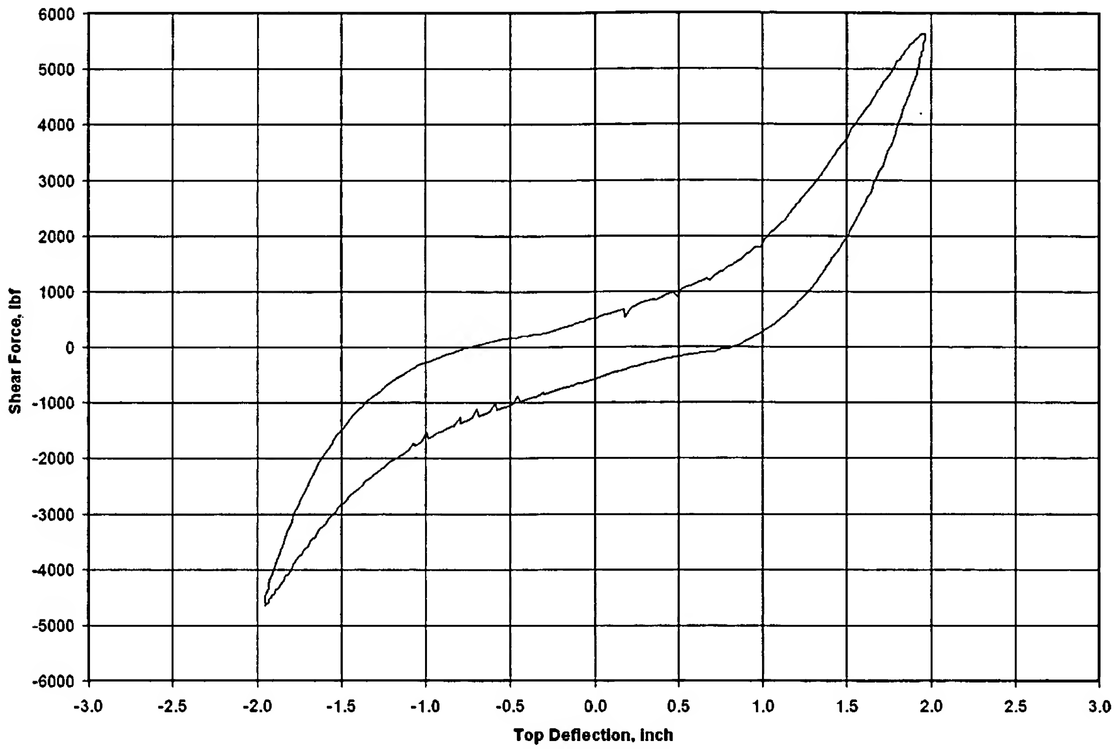

Figure A. Plain OSB Wall @ 2.0" deflection. *Dissipates 5045 in-lb per cycle*

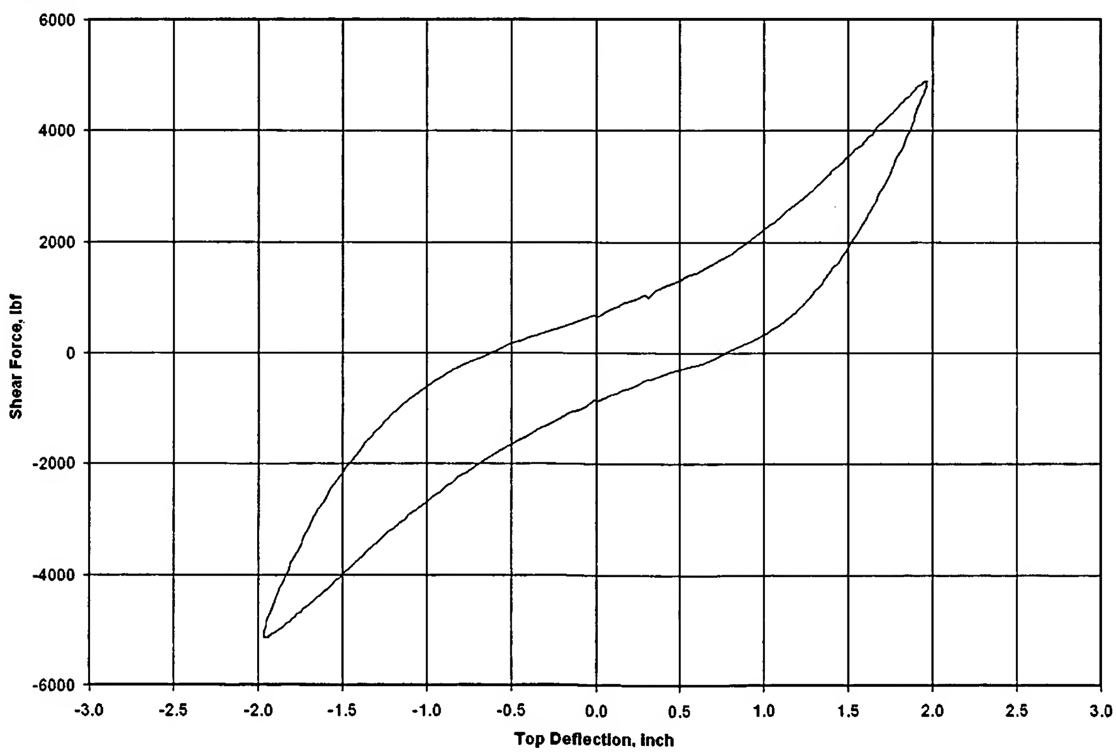

Figure B. OSB Wall with 30x30" window; EPE System @ 2.0" deflection.
Dissipates 6584 in-lb per cycle. 30% greater than a plain solid wall with no window.

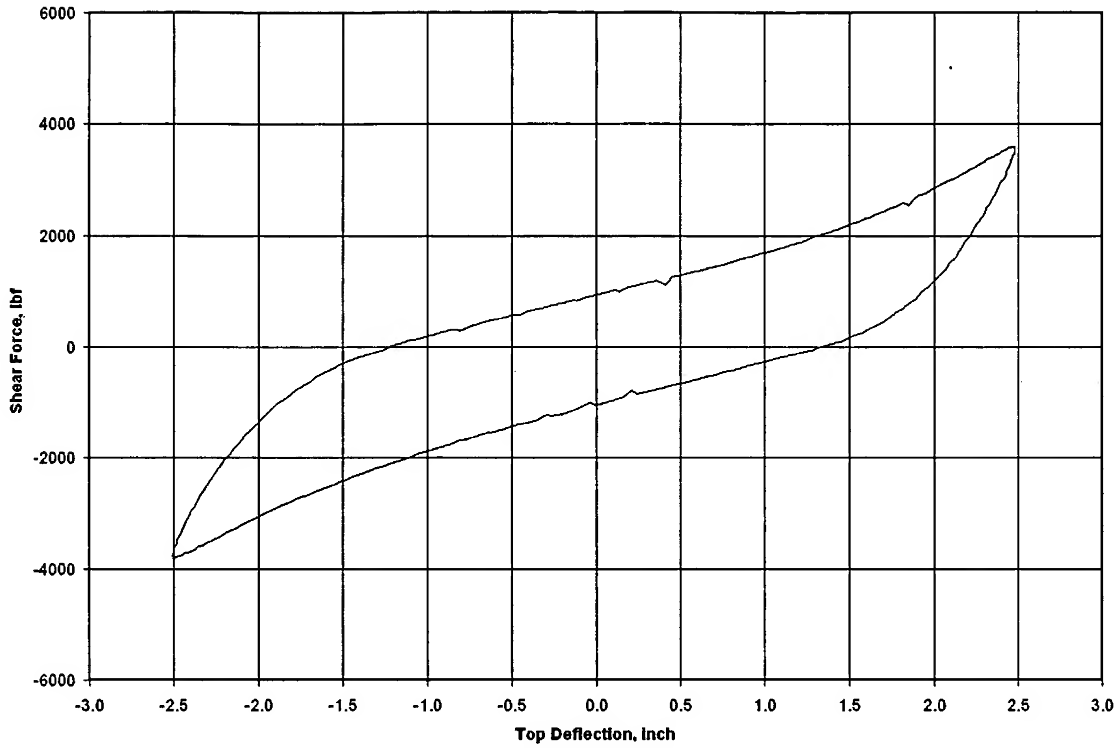

Figure C. OSB Wall with 30x30" window; EPE System @ 2.5" deflection.
Dissipates 8991 in-lb per cycle. 37% greater than same system at 2.0". Meanwhile, a plain solid wall would have failed or greatly lost capacity. Note that 2.5/2.0 = 1.25, so dissipation is greater than displacement ratio alone would indicate. Hardening is reduced by EI-LAND System, tremendously improving dissipation per cycle.

Section 1630.10.2 of the California Building Code is ***amended*** to read as follows:

1630.10.2 Calculated. Calculated story drift using $_M$ shall not exceed 0.025 times the story height for structures having a fundamental period of less than 0.5~~7~~ second. For structures having a fundamental period of 0.5~~7~~ second or greater, the calculated story drift shall not exceed $0.020/T^{1/3}$ times the story height.

(Note: Exceptions to remain unchanged)

1630.10.3 Limitations. The design lateral forces used to determine the calculated drift may disregard the limitations of Formula (30-6) *and (30-7) (Errata Mar. 2001)* and may be based on the period determined from Formula (30-10) neglecting the 30 or 40 percent limitations of Section 1630.2.2, Item 2.

(Note: 1630.10.3 shown for information only with no change.)

FINDINGS:

After engineers began using the '97 UBC they found problems with applying (30-7) for the drift calculations. (30-7) applies only to Zone 4 and was added after the Northridge Earthquake to account for near fault pulses. An erratum to '97 UBC Section 1630.10.3 was issued in March 2001, 3 years following publication, that deleted (30-7) from being applied to drift calculations. However, SEAOC Seismology Committee found that the erratum actually made the drift limit to be less stringent and would allow more slender and flexible buildings than were allowed under the '94 UBC.

The proposed modification was recommended by SEAOC Seismology Committee. It effectively makes the descending branch vary with $1/T^{2/3}$ for drift coordination purposes and make the drift limitations very similar to those of the '94 UBC.

The change from 0.7 seconds to 0.5 seconds in the proposal is needed to avoid a step function in the drift limit. If 0.7 second were retained, the drift limit at T just below 0.7 seconds would have been different from the drift limit just above 0.7 seconds. With the switch to 0.5 seconds, the drift limit just below T=0.5 seconds is the same as the drift limit just above T=0.5 seconds

Briefing Paper 3

Seismic Response of Wood-Frame Construction

Part C: The Role of Wood-Framed Shear Walls

Introduction

This Briefing Paper 3, *Seismic Response of Wood-Frame Construction*, consists of three parts that discuss how earthquakes affect wood-framed construction, including specifics regarding their earthquake-resisting elements, and identifies construction features required for good seismic performance. Part A provides an overview of how earthquakes affect wood-frame construction and explains the load path in wood construction. Part B describes diaphragm chords and collector elements, lateral-force transfer within diaphragms, and lateral-force transfer from diaphragms to shear walls or frames. This Part C discusses wood-framed, shear-wall construction including stiffness issues and hold-downs.

The purpose of shear walls is to provide both the strength and stiffness necessary to resist lateral loads.

This discussion of shear walls (Figure 1) is limited to wood-stud wall framing using wood structural panel sheathing, because this is the predominant type of shear wall used to resist seismic forces in wood-frame buildings. Wood-stud shear walls resist lateral loads from earthquakes and wind, but only the earthquake-resisting aspects are emphasized herein. Other types of sheathing materials are allowed by the code, and steel-stud framing is also an alternative; however, these are not discussed. Also, steel frames used as resisting elements are not discussed.

The purpose of shear walls is to provide both the strength and stiffness necessary to resist lateral loads from the diaphragm immediately above and from the wall in the story above, and to transmit these horizontal loads down one story into either a shear wall in the story below or to the building foundation. Shear walls also usually carry vertical loads from the roof and floors above. However, a vertical-load-bearing wall is not always a shear wall. An exterior bearing wall may have wood structural sheathing applied to the exterior face for architectural purposes and may appear like a shear wall, but not be designed to resist earthquake forces. In engineered buildings, only those walls that are properly connected to the diaphragm and that have been provided with adequate resistance to sliding and uplift forces qualify as shear walls. Buildings using "conventional light-frame construction provisions" as their basis do not contain shear walls; instead they use what are called "braced wall panels." These braced wall panels perform the same function as shear walls, but they are not required to be analyzed for the forces they must resist.

Shear-Wall Strength and Stiffness

Wood-framed shear walls consist of double top plates, studs, and sole or sill plates, sheathed with wood structural panels on one or both sides. The sheathing and its attachment to the framing perform the same function as in a horizontal diaphragm; that is, they resist lateral loads in the plane of the wall. Because shear walls must have all sheathing edges blocked, the wall's strength capacity depends only on the sheathing

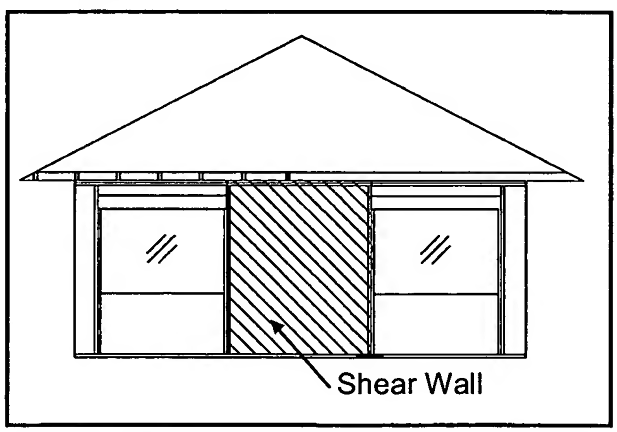

Figure 1 . Wood shear wall along exterior wall line.

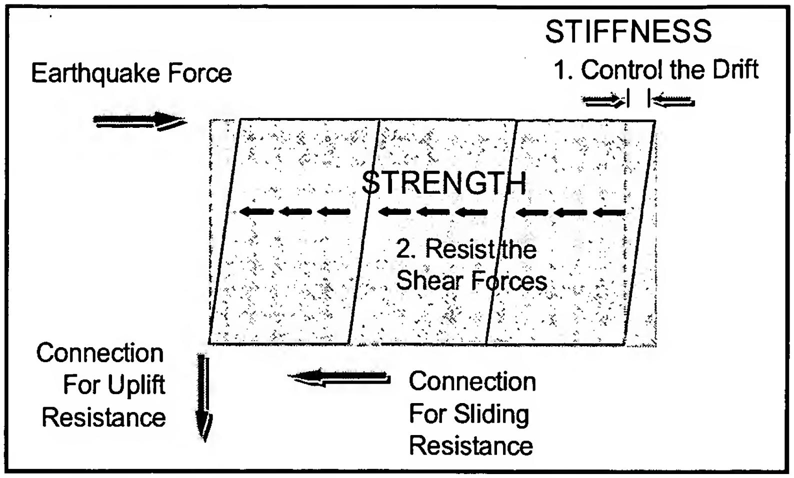

Figure 2. The two functions of shear walls are to provide stiffness and strength.

grade and thickness, and the fastener size and spacing.

Overturning and Hold-Downs

The stiffness of a shear wall, which is its ability to resist in-plane deflection, is a more complex issue, but it is the most important attribute for limiting earthquake damage (Figure 2). A shear wall is essentially a cantilever, fixed at its base but able to move laterally, in its plane, at the top. The amount of deflection that occurs at the top depends on the stiffness of the shear wall, which in turn is affected by the height-to-width ratio of the wall. If two identically constructed shear walls of equal height resist the same lateral force, the narrower wall undergoes greater deflection. This is one reason that the 1997 *Uniform Building Code* (UBC) reduced the maximum height-to-width ratio of shear walls from 3.5:1 to 2:1 for buildings located in Seismic Zone 4 (most of California). Other factors that influence stiffness include the shear strength capacity of the sheathing and its attachment, and the potential vertical slip that can occur in the hold-down connections, located at the ends of the wall to resist vertical uplift loads.

The 1997 UBC reduced the maximum height-to-width ratio of shear walls from 3.5:1 to 2:1 for buildings located in Seismic Zone 4 (most of California).

Shear walls receive lateral forces from the diaphragm above through the connections described above. As shown in Figure 2, lateral forces enter the shear wall along the double top plates. The lateral force acts to slide the wall in the direction in which the load is acting, and to lift simultaneously the left end of the wall shown in Figure 2.

To resist sliding, the shear wall bottom (sole) plate of an upper-story wall must be connected along its length with nails long enough to pass through the floor sheathing and to penetrate into the floor framing or blocking below. Shear walls framed on top of a foundation stem wall or concrete slab on grade must have the sill plate bolted to the foundation or slab (see Figure 3). Proper connection of the bottom plate of a shear wall is essential for good earthquake performance.

As described above, the lifting action at the end of a shear wall is a result of the horizontal force acting along the top plate attempting to tip the wall over (overturning force). While one end is being lifted, the other end is being pushed down, so the studs or post at the wall ends are alternately placed in tension or compression, depending on the direction in which the lateral load is applied. To resist the lifting action, shear walls often have anchor straps or brackets called hold-downs attached to the wall studs or posts at each end of the wall (see Figure 3). It is important that these anchors be located at the wall ends because their

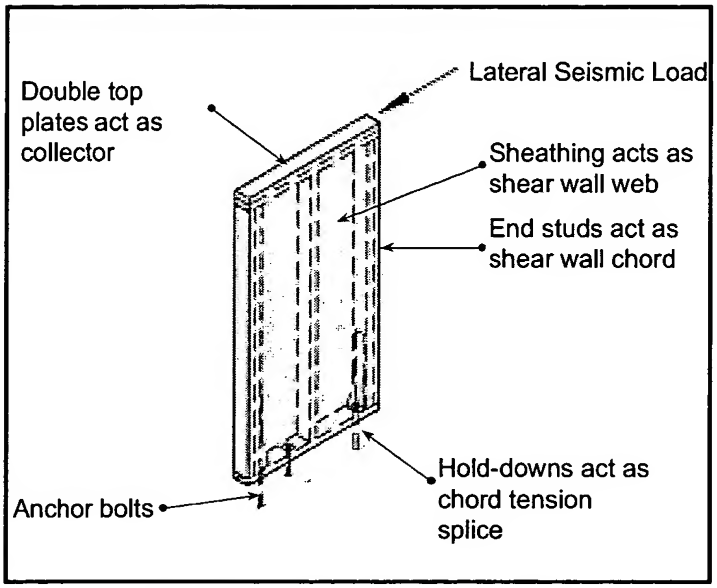

Figure 3 . Typical shear-wall elements.

location defines the length of the shear wall that can be used in the design of the components resisting lateral loads. In upper-story walls, hold-downs must extend through to, and attach to, the wall framing in the story below. Where a wall is not directly below it, the hold-down must attach to a floor beam or wall header to complete the load path leading to the foundation. When walls are framed on a foundation stem wall or slab, the hold-down anchor is embedded in the foundation (Figure 4).

Proper connection of the bottom plate of a shear wall is essential for good earthquake performance.

In addition to providing uplift restraint, hold-downs also limit the in-plane deflection of a shear wall and thereby contribute to its overall stiffness. A certain amount of deflection is expected when a shear wall absorbs earthquake forces, but too much deflection causes damage to other parts of the building that are sensitive to deflection, such as gypsum board or plaster finishes. Improper hold-down installation can result in vertical slip. Vertical movements at the base of the wall allow the top of the wall to deflect horizontally, with the amount of deflection dependent on the height-to-width ratio of the shear wall. If a 1/2-inch vertical slip occurs at the bottom corner of a shear wall that is four feet wide and eight feet tall, it will result in a one-inch horizontal movement at the top. This one-inch deflection is in addition to the horizontal deflection that is expected to occur based on the stiffness of the shear wall itself. Consequently, improper hold-down installation is an important source of earthquake damage. If a hold-down using bolts is incorrectly installed with oversized bolt holes through a wood end post, vertical slip or movement will occur at that location. Vertical slip can also occur if the nut is not tightened on the top end of the threaded rod from a hold-down into the foundation. Mis-alignment of hold-down anchor rods and kinks in steel straps also permit movement as they are straightened when placed in tension by uplift forces.

Occasionally, hold-downs may not be required. One situation occurs when the lateral loads are relatively small compared with the dead load supported by the wall or its end posts. The other situation is when a shear wall is very wide relative to its height. A wide shear wall has the center of its dead load located further from the end of the wall and this distance creates more leverage to resist the uplift at the ends. If the structural analysis shows that the dead load is large enough to resist the uplift

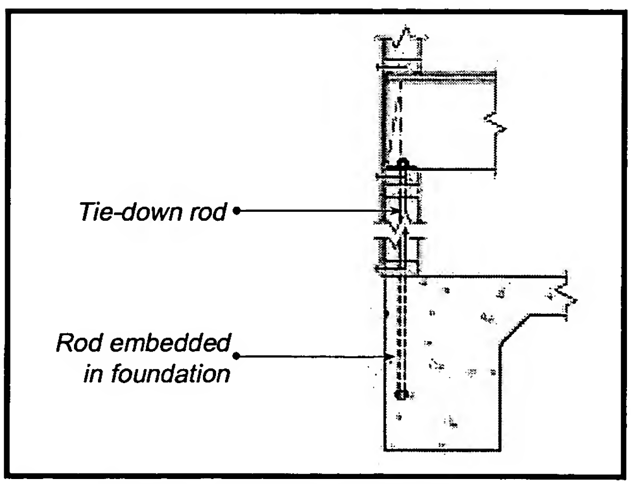

Figure 4 . Hold-down anchorage.

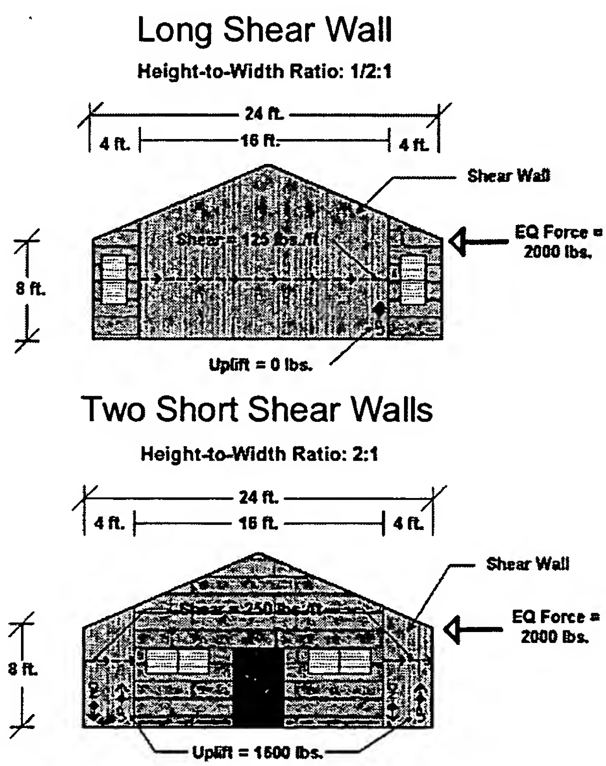

Figure 5 . Comparison of forces in shear walls of different length. There are no uplift forces in the 16-ft long shear wall at the top of the figure, whereas uplift forces at the corners of the 4-ft long shear walls in the lower figure (one wall at each end) equal 1800 pounds for the same lateral earthquake force and uniform deadload (200 lb/ft).

force at the end of the wall, a hold-down is not required. This concept is illustrated in Figure 5.

Reference

ICBO, 1997, *Uniform Building Code*, International Conference of Building Officials, Whttier, California.

About this Briefing Paper Series

Briefing papers in this series are concise, easy-to-read summary overviews of important issues and topics that facilitate the improvement of earthquake-resistant building design and construction quality.

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ICC EVALUATION SERVICE, INC.
Evaluate ■ Inform ■ Protect

March 8, 2004

TO: **PARTIES INTERESTED IN EVALUATION REPORTS ON PREFABRICATED WOOD SHEAR PANELS**

SUBJECT: Acceptance Criteria for Prefabricated Wood Shear Panels, Subject AC130-0204-R1 (PB/BG)

Dear Madam or Sir:

On February 5, 2004, the ICC-ES Evaluation Committee approved the enclosed criteria, effective July 1, 2004.

If you have any questions, please contact Peter Bahlo, P.E., Senior Staff Engineer, at (562) 699-0543, extension 3260, or Brian Gerber, S.E., Principal Structural Engineer, at extension 3260. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,

Kurt Stochlia

Kurt Stochlia, P.E.
Vice President

PB/BG/ll

Enclosure

cc: Evaluation Committee

ACCEPTANCE CRITERIA FOR PREFABRICATED WOOD SHEAR PANELS

AC130

Approved February 2004

Effective July 1, 2004

Previously approved September 2002, July 2002, November 2001, July 2001, July 1997

PREFACE

Evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes. Section 104.11 of the *International Building Code®* reads as follows:

> The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Similar provisions are contained in the Uniform Codes, the National Codes, and the Standard Codes.

This acceptance criteria has been issued to provide all interested parties with guidelines for demonstrating compliance with performance features of the applicable code(s) referenced in the acceptance criteria. The criteria was developed and adopted following public hearings conducted by the ICC-ES Evaluation Committee, and is effective on the date shown above. All reports issued or reissued on or after the effective date must comply with this criteria, while reports issued prior to this date may be in compliance with this criteria or with the previous edition. If the criteria is an updated version from the previous edition, a solid vertical line (**|**) in the margin within the criteria indicates a technical change, addition, or deletion from the previous edition. A deletion indicator (➔) is provided in the margin where a paragraph has been deleted if the deletion involved a technical change. This criteria may be further revised as the need dictates.

ICC-ES may consider alternate criteria, provided the report applicant submits valid data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria set forth in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise demonstrate compliance with the performance features of the codes, ICC-ES retains the right to refuse to issue or renew an evaluation report, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

ACCEPTANCE CRITERIA FOR PREFABRICATED WOOD SHEAR PANELS

1.0 INTRODUCTION

1.1 Purpose: The purpose of this criteria is to provide procedures for recognition of lateral racking loads on prefabricated wood shear panels in ICC-ES, Inc., evaluation reports. These reports consider the panels as alternates to those described in the 1997 *Uniform Building Code*™ (UBC) and the 2003 *International Building Code*® (IBC).

1.2 Panel Justification: All panels shall be justified by racking load tests as described in Section 5. Justification by this method limits panel use to sizes and materials used in the tests.

Panels with height-width ratios exceeding limits in Table 23-II-G of the UBC, or Table 2305.3.3 of the IBC, may be permitted when these panels are qualified under this criteria

Justification for the ability of the panels to resist vertical and transverse loads (out-of-plane) is beyond the scope of this criteria. Nevertheless, substantiating data, in the form of calculations and/or load tests, must be submitted for these type of loads. Information regarding vertical and transverse load capacity will be included in the evaluation report.

1.3 Codes and Referenced Standards:

1.3.1 2003 *International Building Code*® (IBC), International Code Council.

1.3.2 1997 *Uniform Building Code*™ (UBC).

1.3.3 ASCE 16-95, Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction, American Society of Civil Engineers.

1.4 Definitions:

1.4.1 Prefabricated Assembly: A prefabricated assembly is a structural unit, the integral parts of which have been built up or assembled prior to incorporation in the building.

1.4.2 Prefabricated Wood Shear Panels (PWSP): Prefabricated assemblies (with sheathing) designed and constructed to resist in-plane shear loads in walls.

1.4.3 Wood Shear-resisting Frame (WSRF): An assembly defined by one or more PWSP connected at the top to a horizontal beam having a known length and stiffness.

2.0 BASIC INFORMATION

2.1 Testing Laboratories: Testing laboratories shall comply with the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation reports.

2.2 Test Reports: Test reports shall comply with AC85.

2.3 Product Sampling: Components of the test assemblies shall be sampled in accordance with either Section 3.1 or 3.2 of AC85 as applicable.

3.0 PANEL DESCRIPTION

The panel description shall include the following information:

3.1 Dimensions: The width, height and length for each panel type.

3.2 Sheathing Material:

3.2.1 The sheathing material shall comply with a current evaluation report, a national product standard, the applicable code, or otherwise be justified to the satisfaction of ICC-ES. The material shall be clearly identified to determine compliance.

3.2.2 Sheathing material used on weather-exposed surfaces defined in UBC Section 224 or IBC Section 202 shall be protected by a weather-resistive barrier.

3.3 Panel Framing:

3.3.1 Framing members shall be (net $1^1/_2$ inches by $3^1/_2$ inches or net $1^1/_2$ inches by 3 inches).

3.3.2 Grading standards described in the applicable code shall apply to the all sawn lumber framing members. Proprietary wood-based framing members, such as structural composite lumber complying with the ICC-ES Interim Criteria for Structural Composite Lumber (AC47), shall be recognized in a current ICC-ES evaluation report.

3.4 Connections: Connections shall be detailed or adequately described. Fasteners shall be properly specified, including fastener type, size, length and location. Panels shall be constructed with fasteners having approved values. Where no fastener values are recognized by the applicable code, data described in the ICC-ES Interim Criteria for Nails and Spikes (AC116) is required. When used, independent hold-down devices shall be currently recognized in an ICC-ES evaluation report or shall comply with current ICC-ES acceptance procedures. Results of the hold-down tests shall be used in the analysis of the PWSP.

4.0 MISCELLANEOUS PANEL INFORMATION

4.1 Field-cutting of Panels: Field-cutting the panels for wall openings is not permitted except as noted in Section 4.3.

4.2 Field Modification for Framing Members: Holes and notches may be installed in the panels at predetermined locations only. Testing shall include the appropriate size and location of hole(s) and notch(es) as intended for the end use. Holes are not permitted to be greater in diameter than 40 percent of the framing member width, and notches are not permitted to be greater than 25 percent of the framing member width. The ICC-ES evaluation report shall state the limitations for hole and notch sizes and locations ascertained by testing.

4.3 Field Modification for Sheathing: Field modification of sheathing will be permitted for field cutting only at predetermined locations. Testing shall include the appropriate size and location of hole(s) and notch(es) as intended for end use. The ICC-ES evaluation report shall state the limitations for hole and notch sizes and locations ascertained by testing.

4.4 Structural Field Connections: Structural connections between the wall and the structure, made in the field at the time of installation, shall be consistent with the intent of this criteria and necessary for installation of the walls. If there is a field-installed structural header that forms a part of the structural wall system to resist lateral forces (other than simply acting as a collector), and this header is composed of solid sawn lumber (not an engineered wood product), then documentation must be provided to the building official to show that the moisture content of the

sawn lumber header is less than 19 percent at the time of installation.

5.0 PANEL LOAD TESTS

5.1 Purpose: In order to comply with AC130, cyclic shear tests in accordance with the *Standard Method of Cyclic (Reversed) Test for Shear Resistance of Framed Walls for Buildings*, by the Structural Engineers Association of Southern California (SEAOSC), dated August 1, 1996 (revised January 20, 1997), are required, with the following modifications to the SEAOSC document:

1. Section 1.3 of SEAOSC is deleted and replaced by Section 2.1 of these criteria.

2. Section 5.2 of SEAOSC is deleted.

3. Section 5.4 of SEAOSC is supplemented by the following statement: Extrapolation of test results to other panels is not permitted. Interpolation of test results is permitted if the wall is of identical material and the aspect (height/length) ratio falls between the aspect ratios of the known tests being used for interpolation. Additionally, interpolation of test results is not permitted unless it is performed using the shape of a best fit curve as defined from the data points of at least three series of tests at differing aspect ratios.

4. Section 7.1 of SEAOSC is replaced by the following statements: Three tests of each type are required. To apply the average result, none of the results shall vary by more than 15 percent from the average of the three. Otherwise, the lowest test value is used. The average result based on a minimum of five tests may also be used, whatever the variations.

5. As an acceptable alternative to Section 7.3 and 7.4 of SEAOSC, prefabricated shear panels shall be tested according to the CUREE procedures described in Figure 1 and Table 1 of this criteria. For Table 1 and Figure 1, Δ shall not exceed 2.5% of the panel height. If the panel has not failed at the end of the 40 cycles of Table 1, then additional cycles shall be added. Each progressive primary cycle added shall include an increase of 0.5Δ over the previous primary cycle. Two trailing cycles shall follow each primary cycle added with a magnitude 75% of the primary cycle. Appendix A provides additional guidance on this alternative test procedure.

6. Section 8 of SEAOSC is nonmandatory.

5.2 General:

5.2.1 The testing and reporting shall comply with Section 2 of these criteria. No substitution of materials is allowed unless permitted by ICC-ES.

5.2.2 Test Setup: In order to comply with AC130, cyclic shear tests in accordance with Section 5.1 of these criteria shall be conducted on support conditions reflective of the intended use.

5.2.2.1 Foundation-On-Grade: Walls intended to be installed on a foundation-on-grade condition shall be tested on a rigid base.

5.2.2.2 First Floor Raised Floor: Walls intended to be installed on the first floor of a structure with a crawl space foundation shall be tested by placing the walls over a representative floor system constructed on a rigid base.

5.2.2.3 Second Floor: Walls intended to be installed over the second floor of a structure shall be tested by placing the wall on a representative floor system constructed over a representative wall system, all of which is supported by a rigid base.

5.2.2.4 Representative Systems: A floor or wall system shall be considered representative if it is constructed in such a way that the stiffness and strength are similar to that which is expected to be encountered in typical usage. The use of less than full height stud systems under the second floor platforms, and the use of floors constructed with short members, is acceptable. Qualifying the wall performance for all floor framing alternatives is not required. Secondary connections required to transfer shear and overturning through the floor system shall also be constructed with materials and methods typical for the end use. The representative floor/wall systems, as well as the materials and methods for shear and overturning continuity, shall be fully detailed in the test report. Additionally, the ICC-ES evaluation report shall specify these details or other equivalent details.

5.2.2.5 Initial Pretension of Overturning Restraint: If perpendicular-to-grain stress is involved in transferring overturning forces produced by the wall to the foundation, then the overturning restraint device pretension shall not exceed 500 pounds (2,225 N) or when available, the maximum value recommended by the manufacturer for testing purposes.

5.2.3 1997 UBC Design Loads:

5.2.3.1 Allowable Stress Design: The Allowable Stress Design load for the test sample shall be the lesser of the allowable loads based on a drift limit or ultimate load limit, determined as follows:

1. Drift Limit: The Allowable Stress Design load which satisfies the drift limit requirements of UBC Section 1630.9.2 shall be computed as follows:

(a) Maximum inelastic response displacement, Δ_m, shall be defined as either the inelastic drift limit defined in UBC Section 1630.10.2, or the mean displacement at the Strength Limit State of the tested wall assemblies, Δ_{SLS}, whichever is smaller.

(b) Using Δ_m determined above and the R factor approved for the wall, the Strength Design level response displacement, Δ_s, shall be calculated based on UBC equation 30-17.

(c) From the first-cycle backbone curve of the cyclic-load testing, the force corresponding to Δ_s shall be determined. This corresponds to a Strength-level factored resistance.

(d) In accordance with Section 1612.3 of the UBC, this Strength-level factored resistance shall then be divided by a factor of 1.4 to determine the appropriate Allowable Stress Design level resistance.

(e) The drift, corresponding to the Allowable Stress Design resistance load derived in item (d) shall be derived from the first-cycle backbone curve and included in the evaluation report.

2. Ultimate Load Limit: The allowable load based on ultimate load capacity of the PWSP shall be derived by dividing the ultimate test load, as determined by Section 5.1

of this acceptance criteria, by a factor of safety of 2.0. For WSRF, the minimum safety factor is 2.5. The drift corresponding to this allowable load capacity shall be derived from the first-cycle backbone curve.

5.2.3.2 Load and Resistance Factor Design: The values from the test may be used as the reference resistance (*D'*) values when used in accordance with ASCE 16-95, Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction. The design load determined using this approach is not permitted to exceed the Allowable Stress Design load, calculated in Section 5.2.3.1, by a factor greater than 1.4.

5.2.4 2003 IBC Design Loads:

5.2.4.1 Allowable Stress Design: The Allowable Stress Design load for the test sample shall be the lesser of the allowable loads based on a drift limit or ultimate load limit, determined as follows:

1. Drift Limit: The Allowable Stress Design load which satisfies the drift limit requirements of IBC Section 1617.4.6.1 shall be computed as follows:

(a) Maximum inelastic response displacement, δ_x, shall be defined as either the inelastic drift limit defined in IBC Table 1617.3.1, or the mean displacement at the Strength Limit State of the tested wall assemblies, Δ_{SLS}, whichever is smaller.

(b) Using δ_x determined above and the C_d factor determined for the wall, the Strength Design level response displacement, δ_{xe}, shall be calculated based on ASCE 7 Equation 9.5.5.7.1.

(c) From the first-cycle backbone curve of the cyclic-load testing, the force corresponding to δ_{xe} shall be determined. This corresponds to a Strength-level factored resistance.

(d) In accordance with Section 1605.3.2 of the IBC, this Strength-level factored resistance shall then be divided by a factor of 1.4 to determine the appropriate Allowable Stress Design level resistance for use with the alternate basic load combinations of that section.

(e) The drift corresponding to the Allowable Stress Design resistance load derived in item (d) shall be derived from the first-cycle backbone curve and included in the evaluation report.

2. Ultimate Load Limit: The allowable load based on ultimate load capacity of the PWSP shall be derived by dividing the ultimate test load, as determined by Section 5.1 of this acceptance criteria, by a factor of safety of 2.0. For WSRF, the minimum safety factor is 2.5. The drift corresponding to this allowable load capacity shall be derived from the first-cycle backbone curve.

5.2.4.2 Load and Resistance Factor Design: The values from the test may be used as the reference resistance (*D'*) values when used in accordance with ASCE 16-95, Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction. The design load determined using this approach is not permitted to exceed the Allowable Stress Design load, calculated in Section 5.2.3.1, by a factor greater than 1.4.

6.0 PANEL IDENTIFICATION

PWSPs and WSRFs shall bear the fabricator's name and address, evaluation report number, quality control agency name and other information deemed necessary by ICC-ES. The identification shall be visible after the panels are installed. Exterior panels must have the exterior face clearly identified.

7.0 QUALITY CONTROL

7.1 The products shall be manufactured under an approved quality control program with inspections by an inspection agency accredited by the International Accreditation Service (IAS) or as otherwise acceptable to ICC-ES.

7.2 A quality control manual complying with the ICC-ES Acceptance Criteria for Quality Control Manuals (AC10) shall be submitted.

7.3 When PWSPs and WSRFs are installed in jurisdictions governed by the IBC, periodic special inspections in Seismic Design Categories C, D, E, or F shall be provided for nailing, bolting, anchoring and other fastening of components within the seismic-force-resisting system, including connections of the PWSPs and WSRFs to drag struts and hold-downs, in accordance with IBC Section 1707.3.■

TABLE 1—CUREE BASIC LOADING HISTORY FOR PREFABRICATED SHEAR PANELS

CYCLE NO.	%Δ
1	5.0
2	5.0
3	5.0
4	5.0
5	5.0
6	5.0
7	7.5
8	5.6
9	5.6
10	5.6
11	5.6
12	5.6
13	5.6
14	10
15	7.5
16	7.5
17	7.5
18	7.5
19	7.5
20	7.5
21	20
22	15
23	15
24	15
25	30
26	23
27	23
28	23
29	40
30	30
31	30
32	70
33	53
34	53
35	100
36	75
37	75
38	150
39	113
40	113

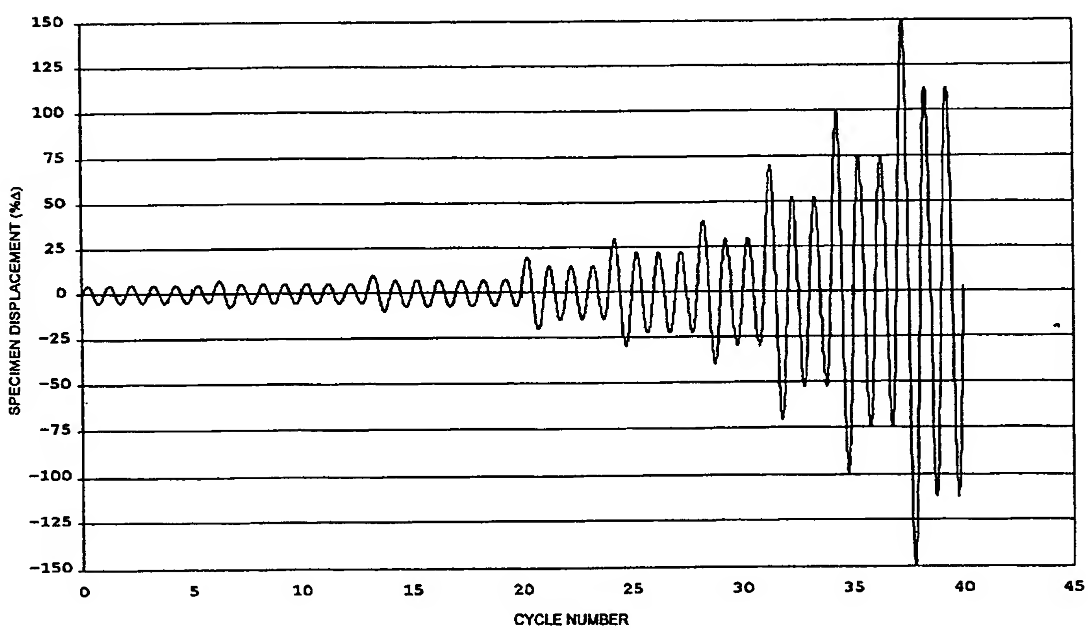

FIGURE 1—CUREE BASIC LOADING HISTORY FOR PREFABRICATED SHEAR PANELS

APPENDIX A

METHOD OF CONDUCTING PANEL LOAD TESTS PER CUREE BASIC LOADING PROTOCOL

Section 5.1.5, Table 1 and Figure 1 are intended to provide an alternative loading protocol to the sequential phase displacement (SPD) loading protocol specified in *Standard Method of Cyclic (Reversed) Test for Shear Resistance of Framed Walls for Buildings*, by the Structural Engineers Association of California (SEAOSC). The alternative loading protocol was developed as part of the CUREE/Caltech Woodframe project (Krawinkler et at., 2000, Sections 1.1, 1.3, and 1.4, and Figure 1).

The basic loading protocol was developed "based on results of nonlinear dynamic analysis of representative hysteretic systems subjected to sets of ordinary . . . ground motions." The process of development the loading protocol had an intended objective that testing would be representative of the seismic demands imposed on components for "1.) Ordinary ground motions that represent design events envisioned by present code and 2.) Multiple earthquakes occurring in the lifetime of the structure." (Krawinkler et al., 2000) The objectives of the development of the CUREE protocol are consistent with the scope of AC130.

The specimen fabrication "should be configured so that the specimen boundary conditions and load application simulate in-situ conditions as closely as possible." (Krawinkler et al., 2000) Therefore, specimen fabrication, test setup, and instrumentation, shall follow *Standard Method of Cyclic (Reversed) Test for Shear Resistance of Framed Walls for Buildings*, by the Structural Engineers Association of California (SEAOSC), with the modifications outlined in Section 5.1 of this acceptance criteria.

The CUREE loading protocol is based upon a percentage of ultimate deformation capacity of monotonic tests. The monotonic tests shall be conducted with similar boundary conditions to the cyclic tests. The loading protocol for the monotonic tests shall follow ASTM Standard E 564.

References

1. American Society for Testing and Materials, 2000. Standard Practice for Static Load Tests for Shear Resistance of Framed Walls for Buildings, E 564-95. West Conshohocken, Pennsylvania.

2. H. Krawinkler, F. Parisi, L. Ibarra, A Ayoub, and R. Medina, 2000. *Development of a Testing Protocol for Woodframe Structures*, Report W-02 covering Task 1.3.2, CUREE/Caltech Woodframe Project. Consortium of Universities for Research in Earthquake Engineering (CUREE), Richmond, California.

MECHANICAL/STRUCTURAL COMPARISON – Building Example

The mechanical and structural functions of the two devices can best be compared using the general example of Figure 5 in Appendix E. (It will be appreciated that this is not a full engineering analysis, but illustrative of the differences in application. Applicants reserve the right to demonstrate full FEA of Mueller or other methodology, as necessary.)

1. Wall Examples with Claimed Active Element

In the upper drawing, the shear loads are applied to the 16 ft of uninterrupted shear wall, and the applied EQ force (2000 lbf) in the drawing is distributed along the shear walls. The height to width ratio of the wall is 1/2 to 1. The shear per foot of wall is 125 lbf.

The walls with the windows are roughly similar to the 4'x8' shear wall with the 30" x 30" opening of Figure 2. of the WJE report. Note that the 4x8 shear wall with the 30"x30" opening achieves a maximum resistance of less than about 1/3 of the solid wall at less than about 1/5th the deflection.

Now, if properly selected Active Elements are installed about both openings as shown in Appendix E, Figure 5, the properties of the window portions of the wall are then generally the same as the centre portion of the wall. The EQ force is now transmitted throughout the entire length of the wall, 24 feet, and the shear load per foot drops to approximately 83 lbf/foot.

Likewise, if properly selected Active Elements are installed about all the openings of the lower wall of Appendix E, Figure 5, the shear loads will be carried by the entire length of the wall, as in the previous case, with a load per foot of approximately 83 lbf/foot.

Note that by use of the Active Elements to contribute to the shear resistance at the discontinuous structural elements of the wall, i.e. the window and door openings, the aspect ratio is enhanced to 1/3 to 1. The Active Elements, by their beneficial action within the wall, have reduced the overturning moments that need to be reacted at the foundation through existing connections that are unrelated to the Active Element system itself. In contrast, the Mueller device actually adds a new load path directly to the foundation.

The load bearing properties of the Active Elements about the openings is entirely different from the multiple-springs of the Mueller device, as is reflected in Applicant's claims. In the case of the window opening, as shown in Applicant's finite element analysis, the upper portion of the right hand Active Element's will close and the lower portion will open when the force is applied as shown in Figure 5. The action of the left hand Active Element will mirror the first, and the action will reverse when the load is reversed. Note that the vertical portion of the shear loads will rotate the axis of the "V" of the non planar portion of the Active Element to the right.

2. Wall Example with Mueller Device

Using the example of the bottom wall of Figure 5 Appendix E, assume the Mueller device is used in place of the narrow shear walls in the example, and its anchor loads are spread over the 4' base of the shear walls shown. The Mueller device will actually have higher overturning moment compared to the original shear walls if the Mueller device has the same initial stiffness as the wall replaced, because it "hardens" - not "softens" as the wall would. The Mueller device provides no means of transferring the shear loads across the discontinuous structural elements, and thus will always produce an overturning moment transmitted out of the wall structure by an A frame or shear panel device.